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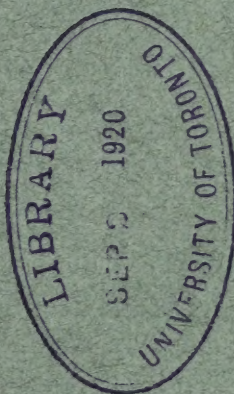
BUREAU OF MINES

FREDERICK G. COTTRELL, DIRECTOR

# CASING TROUBLES AND FISHING METHODS IN OIL WELLS

BY

THOMAS CURTIN



WASHINGTON  
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# CASING TROUBLES AND FISHING METHODS.

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By THOMAS CURTIN.

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## INTRODUCTION.

The Bureau of Mines, in its researches aimed to prevent wastes and to increase efficiency in oil-well practice, has investigated the matter of casing troubles and fishing methods. The results of the investigation are set forth in this paper.

After expensive development work, many wells being drilled for oil have been abandoned because of casing troubles. These troubles in many instances have been thought to be insurmountable, whereas they are sometimes susceptible of solution. In fields where casing difficulties are of daily occurrence, methods have been evolved for combating them. Were these methods more widely known and applied wherever the same conditions exist, the oil industry at large would be greatly benefited. This report attempts to classify these troubles and suggests solutions that will save the operator discouragement and expense.

It is assumed throughout this paper that the reader is so familiar with the ordinary oil-well drilling and fishing methods that detailed explanation is unnecessary. The well-drilling terms that are used herein will be readily understood by those for whom this discussion is intended. However, in order to avoid confusion as to the sense in which some of these terms are applied, definitions are included.

## ACKNOWLEDGMENTS.

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leum engineers; for clerical help, to Miss H. M. Lansche and Miss A. J. Renner; for preparing the drawings, to J. G. Shumate.

### DEFINITIONS OF TERMS.

*Adapter*.—Tool that adapts one size of casing to another size and permits unobstructed passage of tools.

*Bushing*.—A pipe fitting that permits the connecting of two different sizes of pipe.

*Ball-bearing race*.—A steel receptacle containing steel balls that permit easy turning under weight.

*Belled out*.—Spread until bell-shaped.

*Bull ropes*.—Driving ropes used in hoisting tools.

*Cable "reach" and "take up"*.—Stretch and shrinkage of cables.

*Collar*.—Coupling.

*Collar-bound pipe*.—Pipe held in hole by sediment packing between collars.

*Calf line*.—Wire cable used to hoist pipe.

*Circulating*.—Forcing fluid down the inside and up the outside of a string of casing.

*Crank shaft*.—Shaft with "handlelike" crank attached; extends through center of band wheel.

*Collapsed pipe*.—Pipe crushed by outside pressures.

*Drilled off*.—When drillings have accumulated in the hole until the drilling tools barely touch bottom, the tools are said to have "drilled off."

*Drive clamps*.—Steel blocks to be attached to drilling stem to strike pipe.

*Drivehead*.—Circular, steel, "coupling-like" tool. Used to protect pipe coupling from damage from drive clamps.

*Engine balance*.—Iron rim to weight flywheel of engine.

*Engine "off its feet"*.—Engine out of control.

*Formation*.—Material penetrated by the hole, whether hard rock, clay, or running sand.

*Frozen pipe*.—Pipe fast in hole from cavings settling around it.

*Flush*.—Flush with hole. Nearly the same size as the hole.

*Gas pockets*.—Small accumulations of gas confined by formation.

*Hitch*.—Usually refers to the grasping of the wire line or manila cable by means of the clamps hung from the temper screw. In a "tight hitch" the tools are held up so as to take advantage of the elasticity of the cable in "switching" loose tools that have become fast, or, in ordinary drilling, in allowing the tools, when properly spaced, to hit bottom by increasing the engine speed. A "loose hitch" is usually not good practice, in ordinary drilling and is used more often in fishing jobs when enough slack is allowed the cable to permit the "jars" to strike up in order to loosen tools that have become fast in the hole.

*Hitch string.*—String used as marker to determine correct spacing of tools.

*Hitch on.*—To connect cable to walking beam by means of the clamps on the temper screw.

*“Hold.”*—When a fishing tool grasps an object in the hole it has taken “hold.”

*Jar.*—The surface evidence of the blow struck by drilling tools in motion.

*Jars.*—A linked tool. When the links strike together the blow is proportional to the weight of stem or tool above them.

*Jar stroke.*—When the jars are inactive, refers to the maximum stroke of which the jars are capable; when active, refers to the length of stroke being used as governed by the wrist pin in the crank.

*Jerk line.*—Short cable about 21 feet long. By connecting this cable to the crank shaft and to the drilling cable, the tools may be operated without the use of the walking beam.

*Jump a pin.*—To break off the threaded end of a drilling or fishing tool.

*Mud country.*—Localities where the caving of the formation causes much mud in drilling.

*Pipestretch.*—The distance that pipe will pull or stretch before leaving the bottom of the hole.

*Pipe friction.*—Friction on that part of the pipe that is exposed to the formation.

*Pull out.*—To hoist the tools from the hole.

*Rock engine.*—A forward and backward movement of the engine, but not a complete revolution.

*Spudding.*—Drilling with the tools on a jerk line in starting the hole.

*Spider.*—Tool that encircles and holds the pipe by means of steel wedges.

*Screen pipe.*—A perforated pipe with protected perforations to keep out sand.

*Stroke of tools.*—Distance tools travel when operated as in drilling.

*Switching.*—Loosening tools that are fast in the hole with cable tension, but without using jars.

*String of tools.*—Tools used in drilling.

*String up tools.*—To connect drilling tools.

*Tongs.*—Large pipe wrenches.

*Sidetrack.*—To drill past an obstacle in the hole.

*Wristpin.*—The steel pin in the crank shaft to which the walking beam is attached by means of the pitman.

## DISCUSSION OF "MOTION" IN DRILLING WITH DRY AND WET HOLES.

As success in "fishing" primarily depends upon a proper knowledge of tool running, and as tool dressers because of the greater need of drillers are now promoted to drillers more quickly than formerly, the following hints on the running of tools may be of service to many drillers, although it is acknowledged that the skill necessary for efficiency can be gained only through practice.

"Motion" is the engine control applied by the driller in the raising and dropping of cable tools. A driller who thoroughly understands motion has mastered his trade so far as the operation of the drilling tools is concerned.

With each added foot of hole there is an almost unnoticeable change in motion. As the depth of the hole increases, the difference in motion becomes evident when compared with the motion carried at a shallow depth. The adjustment of the steam power to the fall of the tools changes with every variation of the hole.

When drilling in a dry hole, with a manila line, control of the tools becomes more difficult as the depth increases; the engine becomes "weaker" with the greater load caused by the increased depth of hole.

As a premature use of engine balances retards the drop of the tools and compels a slower motion, the common practice among experienced drillers is to avoid the use of the balance in dry-hole, manila-line work where the formation stands up, so long as they can keep the engine "on its feet" without being compelled to run the tools too "loose." With an ordinary drilling engine, when a depth of 2,000 to 2,500 feet is reached without the use of a balance, great skill in steam control is required to maintain the proper motion, or, in fact, any workable motion.

If the opposing drillers, on different tours or shifts, are not equally skilled in steam control, or, as it is termed, in handling the engine, the sensible procedure for the driller having trouble in maintaining the proper motion is to swallow his pride and resort to the use of the balance when he comes on tour, allowing his mate to take the balance off or leave it on at his discretion.

When an engine begins to become unmanageable, time is saved by putting on a balance, and the danger of compulsory loose running in order to retain engine control is averted.

The same rules that apply to manila-line drilling, as regards motion and balances, do not apply when using a wire line. The "reach" and "take up" of a manila line exceeds that of a wire line. In wire-line drilling, the weight of tools and other conditions being the same, the use of balances at lesser depths than would be required with a manila line is a distinct advantage.

The early use of balances with a wire line is especially recommended where drilling jars are run. The quick snap given the tools on "catching" them before they strike, by an occasional excess of motion difficult to avert, often causes the jars to break. The tendency to catch the tools from an excess of motion with the wire line is greater with a "weak" engine. Besides, when using a wire cable it is necessary for the driller to follow more closely the jar observed at the surface. The lack of stretch in the wire line, if the drilling is "good," requires more constant letting out of the screw.

The "reach" and "take up" of a manila cable makes the striking of bottom possible with such a cable long after the bottom would have "faded" before the stroke of the tools on a wire line. The "reach" of the manila cable is easily described by what the older drillers call "lift." For example, the tools would be running "loose" and permitted to "pound." As the tools "drilled off" and commenced to "reach" a noticeable "lift" could be observed after the jar was received at the surface. This lift would feel much as if the handlebar of the screw had exceeded the usual height, which in reality could not occur. As this lift is a demand for "screw," if screw is withheld there will be a slight pause in the motion, soon followed by the engine's being "off its feet," thus compelling screw.

"Lift" is explained as follows: As the tools begin to "reach" on the downward stroke the cable lets out. When the tools strike, the elasticity in the manila cable causes a "taking up" of stretch at the reaction of the tools. Drillers contend that this "taking up" of cable stretch is in reality what is felt at the surface as lift.

With the wire line, except at great depths, the nearest parallel to the lift of a manila cable in a dry hole is "peg-legging" (alternate hitting and missing of the tools). Tools will peg-leg with the wire line, but should not be permitted to do so in a dry hole under ordinary conditions.

If the motion is normal, when the tools "drill off" they will peg-leg; this is a demand for screw. Peg-legging can also be caused by a lack of motion. If there were more reach to a wire line, the tools would not peg-leg so readily. An excess of motion when tools are peg-legging will result in catching of the tools, with danger of breaking the jars.

Both lift and peg-legging are to a great extent dependent upon depth. Lift is seldom discernible above 500 feet. Tools do not easily peg-leg above 300 feet under correctly applied motion.

Many drillers contend that there is little to the mastery of motion with the wire line. As a rule such men, owing to long experience, regulate the motion automatically. Wire-line drilling, however, requires the same mastery of motion—perhaps more easily acquired—as the manila line.

The most common error of the novice with the wire line is the catching of the tools. This is also a common error of drillers accustomed to using a manila line and to the solid jar of the tools in a formation that stands up, when they change to soft and wet hole drilling in wire-line territory. They often mistake the catching of the tools for the solid jar they seek and to which they are accustomed, with the result that they "jack" the line or break the jars, or, in the event of no accident, fail to make progress until they have fathomed the trouble.

The types of formation that a driller must combat vary so greatly that it is impossible to give hard and fast rules for his guidance. In "mud countries"—on the assumption that a wire line is always used where mud and water are encountered—it is advisable to hold the tools up. Some formations are such that when a distinct jar is noticeable further progress, without bailing, is impossible, as this jar indicates that the tools have started to "load up." With continued running the jarring becomes more noticeable, but the tools are making no headway.

Where sticky blue shale is encountered and the tools tend to stick with every revolution of the engine, keeping the motion as rapid as can be safely carried will be found of assistance. Drilling through a formation of this type is necessarily hard on equipment and timidity becomes a greater fault than boldness.

A false jar often occurs in cleaning out muddy and caving holes. As this jar occurs on the down stroke, it is probably caused by the motion exceeding the drop of the tools for an instant; the tools are momentarily retarded with mud, but regain sufficient velocity to keep pace with the engine. No attention, within reasonable limits, should be paid to such jarring, because if the motion is slowed up to conform to the drop of the tools and the jar thus eliminated, the velocity of the tools is so retarded that they merely slide up and down in the mud and water without doing work. Therefore, it is essential to carry sufficient motion to mix the mud with water and to prevent the tools from loading up.

#### **BRIEF COMPARISON BETWEEN MANILA AND WIRE LINES.**

Straining a cable by "pulling" is more destructive to a manila cable than it is to a wire cable. The wire line will stand the heavier pull.

A manila cable "takes up" when idle upon the shaft, or when subjected to dampness, and will stretch when in use. This renders a "marker" on a manila line less dependable than a "marker" on a wire line.

If avoidable, a manila cable should not be used in a "wet" hole. Manila cables are not so destructive to pipe as are wire cables.

## USE OF JARS.

Drilling jars are of short stroke<sup>a</sup> and are run above the stem. They are always used extended in drilling, and their chief purpose is to aid in "switching" tools loose when the tools are stuck. As the weight above that part of the drilling jars which receives the blow, is usually only that of the rope socket and the upper half of the jars, and as the stroke of the jars is only a matter of a few inches—4 to 12 inches, as a rule—a very strong blow can not be expected from their use.

Fishing jars are run on the bottom of the stem. Their usual stroke is 36 or 48 inches, although nearly any length of stroke is obtainable. The force of the blow obtained by the use of fishing jars is governed by hitch, stroke, weight of stem, and motion.

In fishing where "jarring" is expected the engine should be balanced except at very shallow depths. This will insure the engine having enough driving power to do its work under any sudden increase of load. In "jarring up," a "weak" engine results in the belt slipping or being thrown when the beam "turns over" before the "hitch" has been regulated by the screw.

A stem of suitable size and weight for the work expected should be provided, and special attention should be given to the pins and boxes of all tools. The wrist-pin adjustment in the crank shaft should be changed to conform with the stroke of the jars and the length of blow desired. Let it now be assumed that the fishing tool has taken hold of a stationary object at the bottom of the hole and that it is desired to jar up. The "hitch" is obtained by raising the tools with the bull ropes until the jars strike up. Then a hitchstring is tied to the cable at a point even with the top of the hole; the tools are backed slowly down the hole a few feet; the engine is reversed, and the tools started quickly upward. When the string appears at the surface, the bull ropes are thrown. A few inches of slack is then run into the hole, care being taken not to run in enough slack to permit the jars to strike downward upon the "turnover" of the beam after clamping on; then clamp on, "rock" the engine to ascertain whether enough slack has been provided to prevent too great a line tension on the rig, regulate the "hitch" with the screw satisfactorily, and start the beam to turning over. The screw is regulated until the "jar" received at the surface is satisfactory; from then on the force of the blow is governed by regulating the motion of the engine.

To "drive" or jar down, follow the same procedure as in jarring up, with the following exceptions: In taking the "hitch," ascertain at what point the jars strike down, instead of up; tie a string onto the cable

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<sup>a</sup> For definition of jar stroke see p. 7.

when it is even with the top of the hole when the "down" contact of the jars is received; then clamp on at this point.

In driving down if the hitch has been judged accurately, the "jar" will be received at the surface almost simultaneously with the impact of the jars at the bottom of the hole. If after the "jar" is received at the surface the driller observes that several inches of cable travel into the hole before the down stroke is completed, he can judge that the hitch is as about an equal distance "loose."

### USE OF POWER.

The driving and jarring power of a string of tools is tremendous and always sufficient, if applied to the limit, to obtain results of either a satisfactory or an unsatisfactory nature. The driller, therefore, should use discretion in controlling this power. So far as possible, only enough power should be applied to achieve in the safest way the results he desires. The possibility of hidden imperfections in all drilling equipment adds a degree of uncertainty to the most cautious efforts, and often success seems assured when an unnecessary application of power—caused by a natural impatience if progress is slow—will strain a tool beyond its strength and cause it to break.

### STRINGING OF CASING BLOCKS.

There are several methods of stringing blocks for handling long strings of casing. The method most generally approved is shown in figure 1. This method, it will be noted, is for the use of seven lines, but if only five lines are desired, pulleys 3 and 6 may be left unstrung, thus giving five lines.

A common error in stringing casing blocks is to bring the line direct from the calf-wheel shaft to the initial pulley without the reversal noted in *a* and *b* over pulley 1. Without the reversal, the blocks are not in alignment with the hole, and the "starting" of pipe is made difficult. This causes a loss of time in handling casing and may even result in a joint of pipe being screwed in cross threaded, with the inevitable result—a parted string of casing.

### SIZE AND WEIGHT OF CASING.

All casing used should conform in size and weight to the requirements of the work anticipated. It is better to err on the side of safety and provide pipe of slightly greater weight than deemed necessary than to take the chances of collapsed pipe and the possible loss of a hole.

Many holes are "run down to a point." By this is meant that the size of the pipe has been so reduced through necessity that when the well is finished the diameter of the hole is insufficient for practical purposes.

Skilled operators endeavor to start a hole of such large diameter that compulsory landing of the casing at shallower depths than was expected will not necessitate reducing the diameter so rapidly that when the hole is finished it will be too small to meet the needs adequately. This precaution is on the side of safety, because in such a hole the unexpected insertion of smaller casing does not unduly reduce the diameter—the hole being of sufficient diameter when started to discount any reduction in size.

### CASING THREADS.

Many lease superintendents who struggled through the years when eight threads to the inch on casing for drilling purposes was the popular demand, are surprised that this old mistake continues to be common in many sections of the country to-day. It may be said without qualification that pipe having eight threads to the inch is not suited to work requiring long and heavy strings of casing.

Adequate tests and comparisons long ago eliminated 8-thread pipe from practical consideration for use in territory where it must endure severe stress. The superiority of 10-thread pipe has been demonstrated so conclusively that very little 8-thread pipe will now be found, even where it was at one time the more popular. Usage has demonstrated that the 8-thread pipe lacks strength, owing to the deeper cut required for the thread. It was found that the pipe often broke in the thread when subjected to strain. Besides, the 10-thread pipe proved more consistently water-tight and less liable to admit particles of sand and grit, which would bind the thread and destroy it in unscrewing.



FIGURE 1.—Method of stringing casing blocks for the use of seven lines.

Hence it is demonstrated that only in exceptional circumstances can 8-thread pipe be used to advantage in cable-tool drilling, or perhaps in places where the small amount of pipe required makes the size of the thread unworthy of much consideration.

### STRETCHING OF CASING AFTER LANDING.

After a string of pipe is landed the pipe should be lifted and the weight supported at the top on a set of clamps. The object in doing this is to relieve the weight on the lower joints and take up the "stretch," so that the pipe will hang taut and rigid in the hole, care being taken not to pull the shoe off the shoulder upon which it is landed. To neglect this precaution is to place the pipe in danger of being injured by tools coming in contact with the different sections of the pipe that are slightly bowed from the weight of the pipe above.

### "COLLAR-BOUND" PIPE.

Pipe sometimes becomes "collar bound" in a hole. In such an event the pipe can be worked for about the length of a single joint, or about 15 or 20 feet, but will not pull above a certain point. This is caused by mud loading heavily upon the collars and by a mud-laden collar—usually the bottom one—coming in contact with a tight place in the hole. The condition may be aggravated by sand filtering in and finding a resting place upon the mud-laden collar. In such cases it is necessary to keep the pipe in constant movement until it will pull freely past the point of obstruction and pass easily down through the same place; otherwise, such a condition is almost certain to cause the pipe to "freeze" rapidly. (See "Frozen pipe," p. 15.)

When pipe is collar bound, too powerful an effort to pull it through the tight place in the hole will often cause it to become lodged, so that it will neither pull nor fall back to the bottom. This condition should, if possible, be averted by the exercise of patience in working the pipe. Usually collar-bound pipe, if worked patiently up and down in the hole—the collar being pulled gently into the tight place, and the engine then reversed before the pipe has become lodged—will clear itself sufficiently of the sand and mud gathered upon the collars to permit free movement.

When collar-bound pipe "lodges up the hole," the pipe must, of course, be driven back in order that it may be moved again and to prevent its rapid freezing. As a rule, the slightest tap with the tools and drive clamps is enough for this purpose. Unless great care is exercised in control of the pipe, it may be injured in dropping, because pipe thus lodged drops with tremendous force under the impetus of its own weight when once started. Therefore a free drop of even a few inches may result in serious damage, if the pipe strikes

bottom or if a collar strikes an elevator sitting upon an ordinary spider, or any similar accident happens.

### FROZEN PIPE.

The expression "frozen pipe" is applied to casing rendered immovable in a hole by cavings—sand, limestone cuttings, and other gritty substances—settling around the outside of the casing. Casing may be landed without danger of freezing through pure shale mud or in an unbroken shale formation. Shale mud is used as an agency to wall off sands and hold back caving formations, both in the rotary drilling method and in the circulator system with cable tools.

### MUDDING TO PREVENT FREEZING.

The rotary drilling method is by far the best method we now have for mudding off caving sands and shales. Open hole is readily drilled with a rotary rig in such places as will admit of the use of this equipment, and a saving of valuable pipe ensues because the wall of the hole is compelled to remain in place. The wall is actually plastered in place with shale mud. The circulator system with the use of cable tools has a similar effect, but the pipe must be carried in the drilling, and sometimes will freeze very rapidly even with the shale mud constantly circulating down the inside and up the outside of the casing. This freezing would probably be less frequent were the circulator system as thorough in mudding wells as is the rotary method; but it is not and sand filters into the hole.

### STRESS ON PIPE IN PULLING.

The "stretch" of a string of casing is a much-discussed subject. Some maintain that a string of pipe of a given size, when pulled upon, will stretch 1 inch to the 100 feet without parting. Many drillers, when pulling upon a frozen string of 8-inch pipe, insist upon obtaining this amount of stretch. This is a dangerous practice and is often the cause of parted casing. There is no set rule as regards a safety margin of stretch for any given size of pipe, even when the "friction" is known and the general condition of the pipe is assumed to be the best. The problem is wholly dependent upon the judgment of the driller, and even the best judgment is subject to error because of possible flaws in the equipment.

The dangers incident to pulling on frozen pipe are well known. In case it is necessary to resort to pulling upon pipe in this condition, it should be done from the engine house, as it is not unusual for the derrick to be "pulled in," or for the pipe to part near the surface, throwing slack in the calf line. Many men have been injured by the derrick pulling in, and many others by being caught in the slack thrown near the calf-wheel shaft when the pipe parted.

**KEEPING CASING FREE.**

In some districts of this country, principally in California, casing freezes with astonishing rapidity. In the Coalinga (California) field it was not an unusual occurrence for pipe to freeze firmly in 15 minutes, and perhaps be forever lost. To keep the pipe free, various methods were applied, but none was successful in cable-tool drilling, although equipment was introduced that aided in moving the pipe.

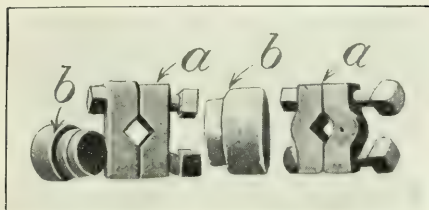
It was extremely difficult to move the pipe every few minutes in order that it might be kept from freezing, and drilling was greatly retarded by the necessity of unhitching and moving the casing. The circulator system of drilling was used with questionable results; the pipe was timed by watch so that it might be permitted to stand as long as possible, until the danger of freezing was actually acute, in order that drilling could proceed more regularly. However a heavy loss of pipe and a rapid reduction of the diameter of the hole continued for years.

It has been observed that after the wall of a hole has become saturated with oil the pipe is less liable to freeze and oil sand is not nearly so prone to freeze pipe as are dry or water sands.

At a well belonging to the Amalgamated Oil Co., of California, the drilling foreman, Thomas N. Kellett, issued instructions that the well be circulated with oil in the hope of relieving a string of casing which tended to freeze so rapidly that it had to be kept in constant motion to permit further progress. The experiment proved very successful, relieving the tendency to freeze so much that the pipe would stand safely for hours.

Quite the reverse was the experience of the drilling foreman, H. A. Winger, of the Shell Oil Co., of California, who was confronted with the problem of continuing work on a well that was in the oil sand and for this reason was not expected to freeze pipe readily, but, nevertheless, showed a decided tendency to do so. The pipe would not stand more than 15 minutes without freezing firmly, and more often 7 minutes rather than 15 was the margin of safety. It was decided to pull the casing and put a screen pipe on the bottom joint. After this was done, the pipe was rendered free enough to permit two to three hours to elapse without moving it.

From the above illustrations it can be seen that the action of freezing pipe is very erratic and that oil may fail as a means of relief for freezing. However, in territories where the formation is very similar to that in California and where oil is encountered in small quantities at shallow depths, as in parts of Wyoming, Mexico, and Burmah, usually pipe will stand many months without the slightest tendency to freeze.



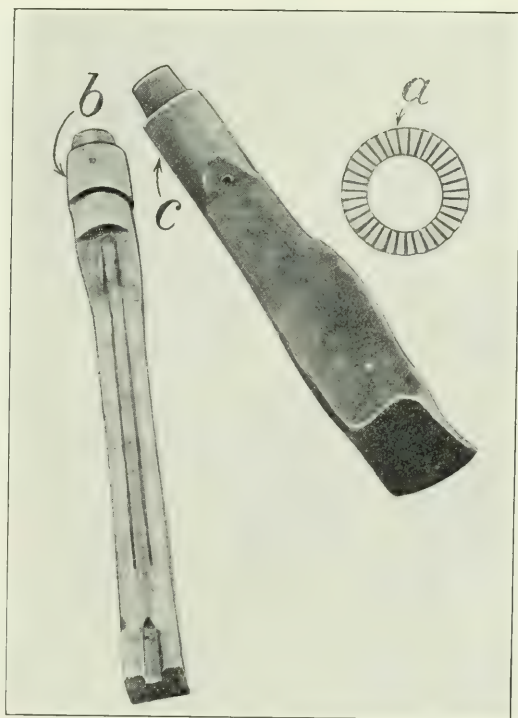
A. DRIVE HEADS AND DRIVE CLAMPS.



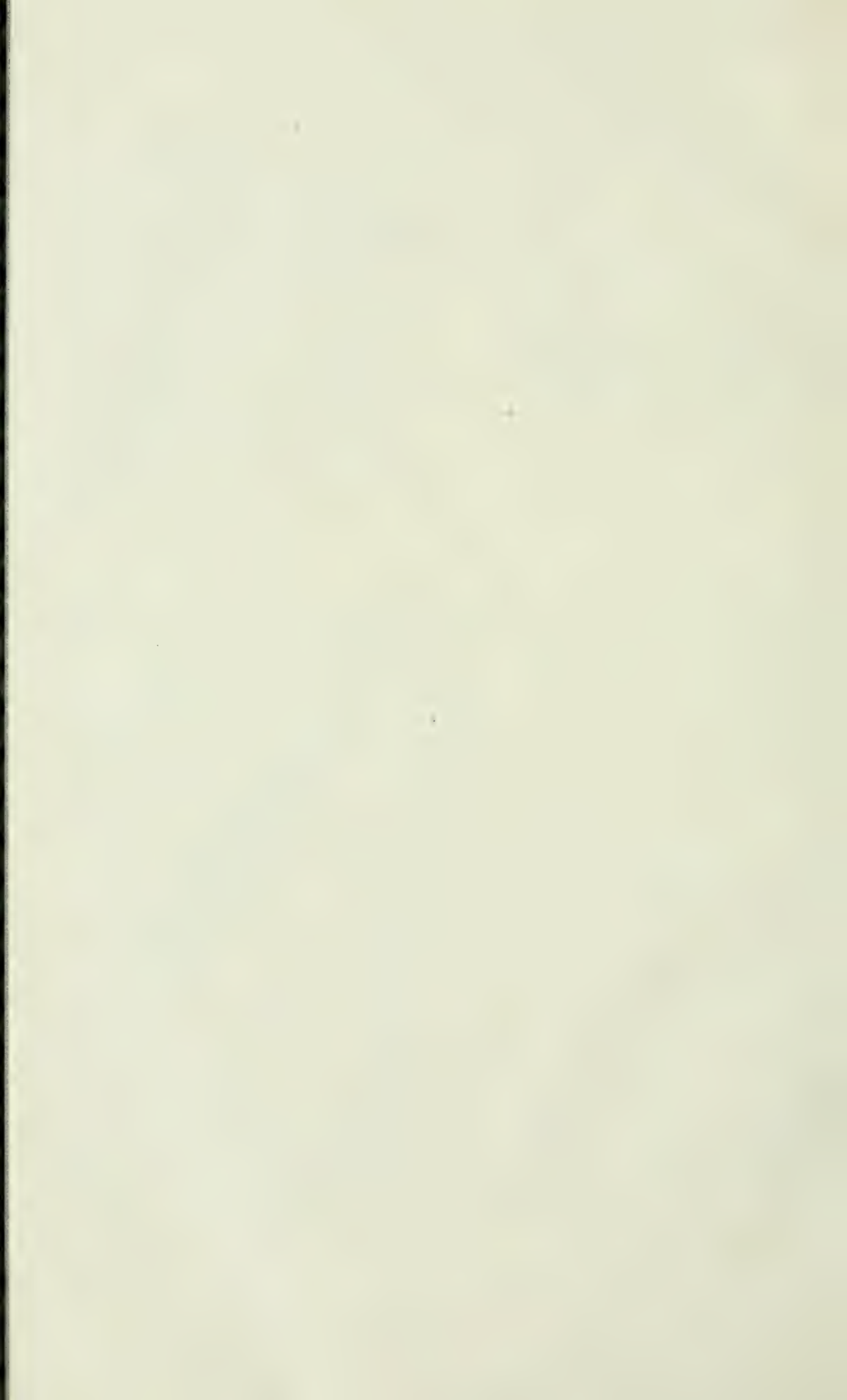
B. SWAGES.



C. OVERSHOT.



D. CUTTING FACE OF MILLING TOOL, *a*, AND SPUDS, *b*, *c*.



## USE OF SWINGING SPIDER.

The swinging spider (fig. 2, p. 18) is probably one of the most useful inventions introduced in recent years for the handling of casing in drilling oil wells. The walking beam and screw operate between the reins of the spider, absolutely without hindrance, and the pipe may be lowered at will by merely raising the calf-wheel brake without in any way interfering with drilling.

Should it be necessary for any reason to drive the pipe, it can be done safely with the use of this spider, as the spider does not contain teeth slips when in ordinary use, but is fitted with lugs that fit snugly beneath the pipe collar and permit the spider to move freely up and down the pipe. (See fig. 2.) In long strings of casing or when it was necessary to do any severe pulling, it has been found expedient to use teeth slips and catch the top joint of pipe below the coupling to avoid accidents resulting from pulling off the coupling.

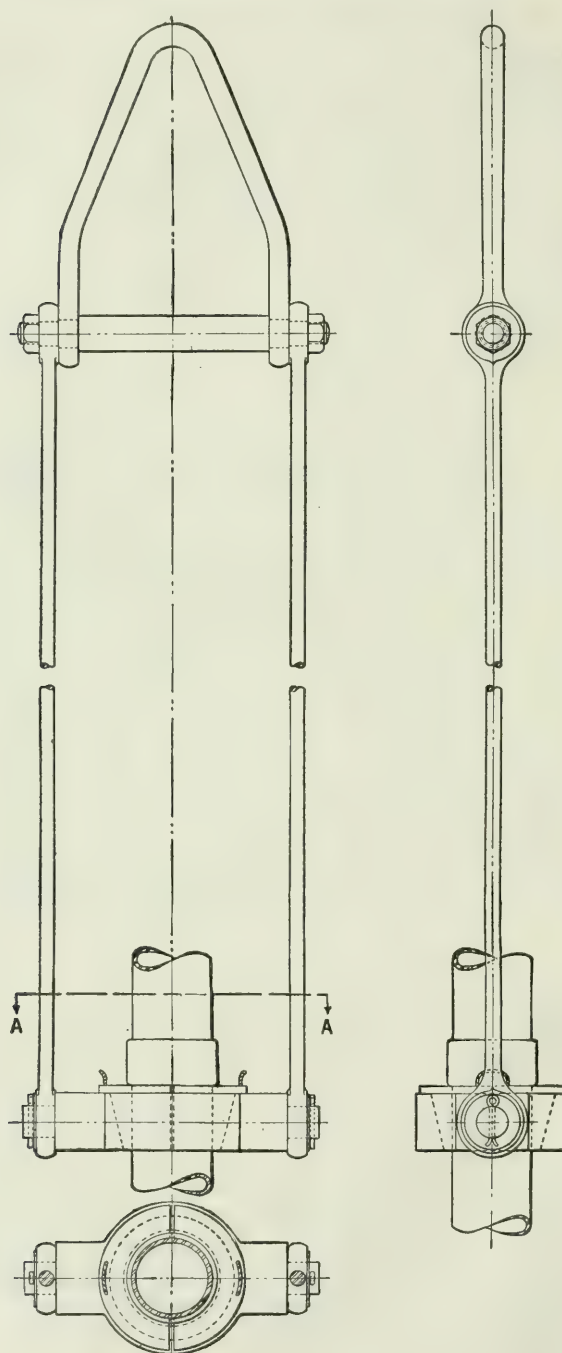
When drilling is in progress, as formerly stated, the pipe is suspended upon the casing blocks and is governed by the calf wheels, being permitted to slip a few inches, without even checking the drilling motion, whenever the driller desires to move the pipe.

In driving, the spider can be permitted to slip down the pipe a few inches; then, if the pipe is driven free and drops with any great velocity, it will be caught by the spider, and all danger of abrupt stopping will be eliminated by the spring of the lines and derrick. For such work the swinging spider is used in conjunction with an ordinary spider. The smaller spider rests upon blocks in the collar and is used only to hold the pipe when the swinging spider is removed for the purpose of inserting a joint, or for any similar purpose. The spider shown in figure 2 is in use by the Shell Co. of California, but is only one of several types that have been introduced.

## DRIVING PIPE AT TOP OR SURFACE.

The best plan, where frequent driving is expected, is to keep a drivehead in continual use in order to protect the threads of the top coupling from the wear of the cable, and also to avoid unnecessary breaking of tool joints—to pass the tools through the drivehead—when time is an important factor. The ordinary drilling tools may be used for this operation. The method is almost universally understood among operators, and is similar to the spudding method used in starting a hole, with the exception that strong drive clamps (see *a*, in Pl. I, *A*), are firmly fastened on the wrench grip at the top of the stem, and a drivehead, *b*, is inserted in the pipe coupling to protect it from the blow of the clamps when the tools drop.

Driving is resorted to when it is desired to force a string of pipe down to obtain a seat, as in cementing, and in other work where pull-



Section through A-A

FIGURE 2. -Swinging spider

ing the pipe up and underreaming has proved detrimental, but there is still reason to believe that the pipe can be landed at a greater depth without injury by driving. The following discussion, however, deals only with driving as a means of loosening frozen pipe.

Drive pipe has been manufactured for many years, but is seldom used. Drive pipe differs from the pipe in ordinary use in that it "shoulders" in the couplings—that is, the thread end of a joint may be screwed into the coupling of another joint until the ends of the two joints butt against each other, with no space between. The use of this pipe is so exceptional that all further references herein are confined to the pipe in ordinary use.

In driving pipe at the surface of the ground, the chief consideration should be the weight per foot of the casing, and the next consideration should be the length of the string of casing. Driving pipe at the surface is now generally confined to strings of medium length. The jar-down spear (fig. 3) is used for the longer and heavier strings of pipe. In surface driving, the string of tools should be stripped below the stem of any fishing tools or jars. No injury results if a bit, or similar tool, is left on the stem, but a set of jars hanging loosely on the stem, or even weighted with a tool, are very liable, if not almost certain to "jump a pin" and drop to the bottom of the hole. In driving to loosen a string of frozen pipe, the procedure is as follows:

With jars at the top of the stem and no tools other than a bit on the bottom of the stem, the tools are run through a drivehead in the coupling of the casing, and a set of drive clamps is fastened upon the square part of the stem at the top. A "jerk line," as in spudding, is then run from the wrist pin of the crank shaft to the slack line run from the bull-wheel shaft, and the two are fastened with a spudding shoe and hook. With the bull rope off, the bull wheels are turned by hand to take up the slack in the cable, care being taken to protect the coils on the shaft from injury by "crowding." After the slack is taken up, the bull-wheel brake is tied down, and the engine is started. The tools now rise and fall with the revolution of the crank shaft, and drop with great force upon the drivehead in the coupling. The pipe will give several inches under the force of the blow, depending upon the length of the string and the point at which frozen, and will spring back with great rapidity. The pipe should be carefully marked. If it drives readily as much as 1 inch, this is a very encour-



FIGURE 3.—  
Drive-down  
spear. When  
tripped, the  
slips grip the  
pipe, stopping  
further descent  
of the tools.  
This spear  
pulls out read-  
ily.

aging sign. If after continued driving no progress has been made, resort must be had to some other method in order to loosen the pipe; but if the pipe drives, it is well to pull the pipe back the length of the distance driven, or a greater distance if this can be done safely. The pipe should then be driven down again.

Movement is the object sought. As a rule, when the pipe will drive 1 or 2 inches readily, it will pull back an equal distance, or slightly more. If the pipe is then driven again, upon the second pull the distance will usually increase slightly. This procedure should be continued until the pipe will work up a joint and "pass collars." It should then pull quite freely.

In driving pipe, the "spring" and "vibration" of the pipe are the means of loosening the enveloping sediment. This being so, the same results can usually be achieved more safely by putting the wrist pin in the second hole of the wrist pin and applying power with reserve. It is a question whether a rapid light stroke is really more beneficial than a slower but more powerful blow.

Before shooting (see p. 40) or splitting (see p. 39) a string of casing in a hole about to be abandoned, driving should always be resorted to if the pipe is frozen, unless the conditions are known to be such as to make the risk attendant upon pulling and driving too great.

Some of the expedients that have proved successful in freeing frozen pipe in conjunction with driving and pulling are:

1. Bailing the hole dry of all fluid.
2. Filling the hole with water.
3. Ripping a hole in a bottom joint of pipe to permit sediment behind the pipe to run in the hole.
4. Drilling hole ahead.

Top driving is sometimes, but very rarely, the cause of injury to pipe. The chief tendency of this method of driving is to loosen the couplings, and, if much driving has been done, those couplings that will respond to screwing from the surface should be tightened before pulling.

Pulling upon pipe is dangerous both to men and to the pipe. Courage, tempered with judgment, is an essential factor in the success of the operation, and as there is no absolute rule for accurately judging the strength of the pipe or other equipment, the exercise of anything approaching exact knowledge in such work is difficult.

#### DRIVING WITH JAR-DOWN SPEAR.

A long, heavy string of pipe is more safely driven with a jar-down or drive-down spear than from the surface. Surface driving is liable to break a die collar or nipple (see figs. 5 and 6, p. 22), and if such a collar or nipple has been used for fishing purposes and is still

in the hole, the drive-down spear (see fig. 3, p. 17) may be used to take hold below the die coupling.

As a long string of casing is more liable to be injured from surface driving than a short string, the jar-down spear is generally used where the string of casing is more than 2,000 feet long, and it is also used by many companies at lesser depths.

The point at which casing is frozen can be determined very accurately with a jar-down spear. Pipe vibrates from a blow when free. This vibration is plainly audible and discernible at the top of the hole. If a hold is taken with the jar-down spear in that part of the casing that is frozen, there will be no apparent effect upon the pipe at the surface. If the spear is raised from time to time and the jarring action repeated, the moment the spear has been raised above the point where the pipe is frozen, a distinct vibration of the pipe will be noted. This is called finding the "friction" on a string of casing; the process consists of taking hold with a jar-down spear in a bottom joint of casing and jarring down, raising the spear and repeating the procedure until the pipe vibrates. When the pipe starts to vibrate it is judged free from the surface to the point at which the vibration started, and frozen from that point to the bottom of the hole. In driving with a jar-down spear the hold is usually taken in one of the bottom joints of pipe.

The slips on this spear are so constructed that they slip up an inclined plane and out against the sides of the casing, and prevent the tools from going farther down the hole. By taking the first hold near the bottom of the casing before tripping the spear, the weight of the casing above assists in the driving. As it is necessary to change the hold of the spear at frequent intervals, and as this can be done only by pulling the spear up the hole, a bottom hold is necessary unless it is desired to work the spear above the point of friction.

In jarring down, the tools are strung as in fishing, with fishing jars below the stem and jar-down spear screwed on jars. The process consists of simply setting the tool and driving down with stem and jars. The hold of the spear must be changed frequently to prevent the pipe from bulging at the point of contact with the spear slips.

As in surface driving, movement is sought. If the pipe moves it is well to pull and work it up and down as much as possible, giving the débris behind the pipe opportunity to break in around the shoe and thus free the pipe.

### FISHING WITH DIE COUPLING.

Steel die nipples and die collars (figs. 4, 5, and 6) are used to recut threads on a lost string of pipe and to act as a coupling after the screwing on has been completed. They are made so that they may be inserted in a collar or over the thread of a joint of pipe, and,

when necessary, may even be used where the thread of the joint has been broken off and the top of the pipe left intact.

A die coupling, either steel nipple or collar, can be used successfully at any reasonable depth. The die is a case-hardened tool and can not be driven upon without danger of breaking, although it may be pulled upon with safety when properly screwed on. Such tools

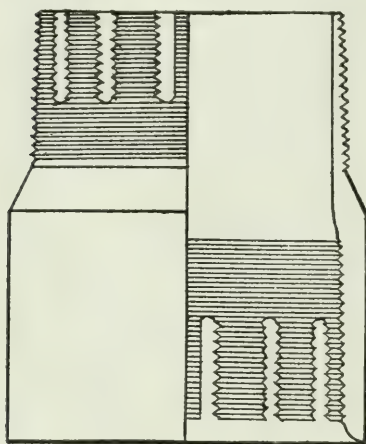


FIGURE 4.—Combination casing nipple.

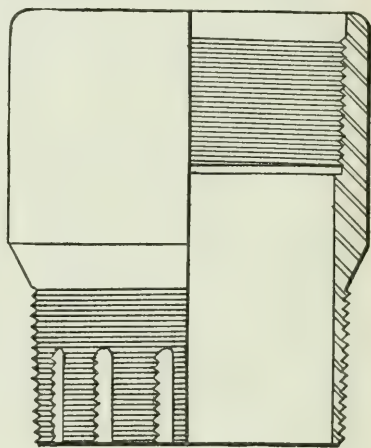


FIGURE 5.—Die nipple.

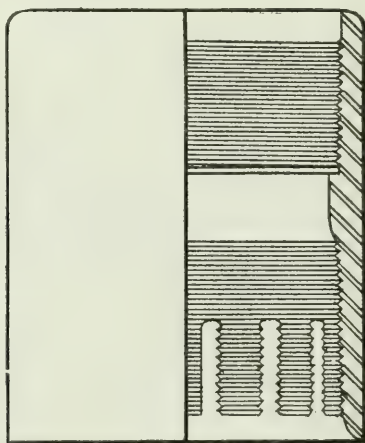


FIGURE 6.—Die collar.

can not be used successfully on a "water string," as they are not water-tight. A die coupling should be selected that will not hinder the passage of tools; if not carefully selected, it may be discovered after the parted pipe is coupled together by means of the die nipple or collar that various drilling tools which are "flush" with the hole will not pass through the die coupling. This often happens with die nipples and collars used in the Mid-Continent field, and is a matter of

serious concern if the pipe thus coupled is frozen or in such condition that pulling it out is not feasible. It is then necessary to turn all tools, such as underreamers, swages, etc., down to a size that will permit their free passage through the die coupling, because the unscrewing of such a coupling at any great depth, without unscrewing collars above the coupling, is almost impossible.

#### METHOD OF SCREWING ON.

The die coupling is placed upon the bottom of a string of pipe of the same size as the pipe lost in the hole. This "fishing string" is then run into the hole until the tool rests lightly upon the upper joint of the lost string. The fishing string is then turned slightly until a "drop" is felt at the surface. This "drop" is evidence that the tool has dropped into place and is resting properly upon the lost string, ready for screwing. No drop will be felt if, perchance, the tool landed in perfect order for screwing when first set upon the lost string. Pipe tongs are now put to work turning the pipe at the surface with engine power, the weight of the upper pipe being permitted to rest upon the lost pipe.

For some sizes of pipe ball-bearing races have been provided, which sit beneath a collar and on elevators and are adjusted to support the unnecessary weight of the fishing string. These races, however, are seldom obtainable, so it is here assumed that they are not in use.

As the pipe is screwed on with the engine and the die coupling begins to cut threads, little satisfactory progress will be made unless a second pair of tongs is used to hold the back spring—caused by the torsion obtained on the pipe—before the die coupling at the bottom turns and cuts.

A mark should be kept upon the fishing string. As the die coupling screws on when cutting its way, the fishing string will settle the same distance if no couplings in the fishing string also screw up. However, the couplings are almost certain to take up, but as their action can be readily felt, the amount of this "taking up" should also be judged. As the die coupling makes headway a continuous increase of power will be required to turn it. The point at which to stop screwing is determined by the surface indications resulting when engine power is applied, such as the strain on the tongs, the amount the pipe has settled, etc. The two strings of pipe should now be fastened firmly together and in condition to be pulled when desired.

#### USE OF CASING BOWL.

P. D. Tanguay, a master mechanic employed by the Shell Co., of Coalinga, Calif., manufactures for the use of that company a casing bowl, shown in figure 7. The drilling foreman of this company uses

this tool almost to the exclusion of die collars in work that ordinarily calls for a die collar. The slips of this tool, being very thin, permit a hold to be taken upon the outside of the lost string of pipe.

Like the die coupling, a casing bowl can not be driven upon and will not exclude water. It will, however, permit a free passage to all tools and is capable of withstanding very hard pulling, but is only serviceable when there is no coupling on the top joint.

W. A. Snyder, also of the Shell Co., who has had occasion to use this tool on numerous occasions, regards it as more adaptable to the same class of work than the die coupling, as the time and labor incident to screwing on with the die coupling is unnecessary with the casing bowl.

The casing bowl is run into the hole in a manner identical to that described for the die coupling, but once the bowl has slipped over the lost string of casing, its action is instantaneous, as it takes hold of the lost string when pulled up, and the pipe is thus connected.

### "BAD PIPE."

Frequently pipe remaining in a hole for some time will "go bad." This expression refers to pipe that has become dented from a "stone bruise," is in a state of partial collapse from outside wall pressure or gas pockets, or perhaps is split and partly flattened. The pulling of such pipe for the purpose of replacing the damaged joints is often inadvisable because of the danger of parting the pipe at the "bad

place," leaving the lower part of the string in the hole. Such pipe is often "frozen," and attempts to free it would cause the weakened joints to part.

Bad pipe is usually first detected by the bailer hesitating in its drop as it is let down the hole. This hesitation recurring continuously in the same place leads the driller to suspect that the pipe is giving way at that place. As any slight dent in the casting is bound, from time to time, to meet the full shock of all tools being run in the hole,

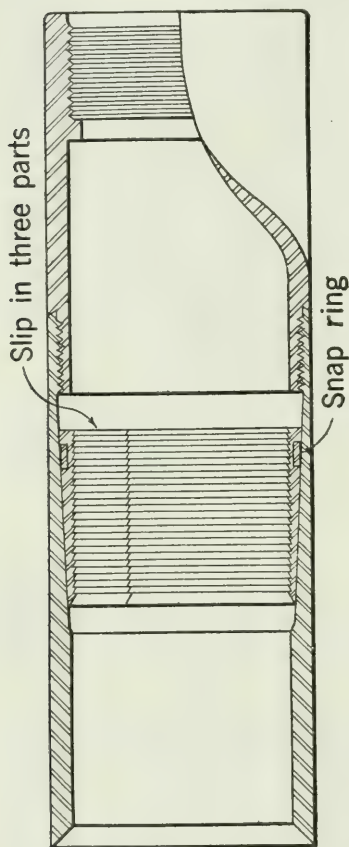


FIGURE 7.—Casing bowl; may be used in place of a die collar; permits passage of tools.

it is usually only a matter of time until such a place in the casing becomes so impaired as to cause the bailer to "stop up." Before the pipe has become too badly damaged the bailer can be worked past the obstruction and at times will entirely miss it, gliding past with scarcely a halt. The obstruction is next noticed with the drilling tools and eventually becomes so "bad" as to cause the tools to "stop up." The bailer will seldom pass through pipe sufficiently "bad" to obstruct drilling tools in their passage, although this condition may be overcome for a time by replacing a full-size bailer with one of smaller diameter.

#### SWAGING.

One of the remedies for "bad pipe" is swaging. The swage, Plate I, *B* (p. 16), is a heavy piece of steel, oval in shape, with a small groove cut into the steel as a watercourse. At its greatest diameter the swage is but a fraction of an inch smaller than the diameter of the casing through which it must pass. Thus, casing with a 10-inch inside diameter should permit the entrance of a swage  $9\frac{7}{8}$  inches in diameter. As the ultimate desire is to "run" a swage of the greatest diameter that the size of the casing will permit, a variance of even one-sixteenth of an inch is a matter of importance.

The swage is run below the stem, with long-stroke fishing jars immediately above the swage. The tools are run into the hole until the swage stops upon the "bad place" in the pipe. The "hitch" is taken for "driving" or "jarring down" as described on page 11. As the swage drives ahead from the impact of the stem and jars, the screw should be let out enough to keep the jars continually hitting down. When the swage has been driven through the "bad place" and has entered the "good" pipe below, the tools will swing free. When this occurs, the weight of the heavy swage being now added to that of the extended jars causes an unmistakeable change in "motion" and cable tension. An attempt should now be made to pull the swage back up through the "bad place" in the casing. In all probability the swage will have to be "jarred" back through this place. The operation of driving the swage down through the "bad pipe" and jarring it back through the same place should be repeated until the swage will pull freely through the impaired pipe. It can now be safely assumed that the pipe has been extended to its normal size.

#### REMARKS CONCERNING SWAGING.

When a difficult swaging job is expected, the common method of procedure is to drive a swage of a small diameter through the "bad place" first. This swage is then withdrawn and a swage of greater diameter is used. This procedure is repeated until a swage of maximum diameter is driven through the impaired pipe.

If a swage has been driven through a split joint of casing and cavings are falling into the hole through the split, great care should be taken to prevent the cavings from wedging the swage in the hole—the tool being so nearly “flush” with the hole that any hard obstacle may cause it to wedge. Pulling the swage above the split pipe from time to time will act as a preventive against wedging, and in case the swage does not pull freely it should be pulled out and cleaned. A swage wedged in casing is a difficult tool to remove, as it is not unusual to jar a pin off in attempting to jar the swage past cavings or broken pieces of pipe that may accumulate above it, unless care is taken. It is always possible to jar a swage up through pipe through which it has been driven if no débris has accumulated upon the top of the swage.

Pipe has seldom, if ever, been severely injured by a swage, but should not be swaged, if avoidable, unless sitting on a shoulder or bottom. Pipe, if hanging in the hole, may easily be parted with a swage.

Swaged pipe frequently goes bad a second time, necessitating a repetition of swaging. It may be considered that the pipe is weakened with each swaging. Where possible an inside string of pipe should be inserted with a tapered guide of wood or cast iron upon the bottom of the shoe to guide the shoe through the swaged pipe. This pipe will ordinarily keep the hole in better condition.

Tools with swage attached should never be raised above a “bad place” in the casing and allowed to descend swiftly. When this is done, if the swage stops in the “bad place” in the casing and is then knocked through with one blow by the descending stem and jars, the swage being heavy may fall so forcibly as to “jump” a pin when the jars receive the weight of the swage. This practice is especially dangerous where two sets of jars are used.

### COLLAPSED CASING.

Pipe in a hole usually goes “bad” gradually, and may sometimes collapse gradually, but as a rule collapsing takes place instantaneously and often above tools in operation, causing them to be shut in below the collapsed pipe.

A typical example of collapsing casing occurred in a wild-cat well in Colombia, South America. The hole was 2,210 feet deep. Ten-inch pipe of a standard make weighing 40 pounds to the foot was being used. The pipe was in good condition, but because of circumstances unnecessary to explain, it was decided to land the pipe and bail the hole.

The pipe was landed and bailing of the hole was commenced. The water was lowered to a depth of 1,150 feet. At this stage of the work the pipe collapsed at 1,600 feet. There was a sharp report, resembling

the explosion of a charge of dynamite in the hole, and a rush of air which blew the hats off the men who were standing near the hole. This was followed immediately by a column of water that gushed to a height of about 50 feet. The water was followed by gas, making it necessary to extinguish the fires under the boilers.

After collapsing, pipe will often be completely sheared off, and the damaged pipe pulled out will be flattened and split. The presumption is that the top of the pipe left in the hole is in the same condition. However, more often the pipe, although badly flattened and split, will cling together, which necessitates driving at the top with tools and drive-clamps before the shattered pipe will break.

#### DRILLING PAST OR SIDETRACKING CASING.

Drilling past pipe is a comparatively easy matter in caving territory, but a very difficult undertaking where the formation is hard and "stands up." The necessity for drilling past pipe in hard territory, however, is far less frequent than in caving territory. The conditions liable to collapse are more frequently found where the formation caves, and in such a formation the remedy is the more easily applied.

#### TIME CONSUMED IN "DRILLING PAST."

When confronted with a job that necessitates "drilling past," the operator, unacquainted with the process, believes that the time and risk involved may make moving the rig and starting a new hole more practical and is doubtful as to which is the better method of procedure.

When the territory is suited to "drilling past," the redrilling often proceeds, after a successful initial start, far more rapidly than did the original drilling of the same formation. The greater facility of redrilling is accounted for by the formations having been somewhat broken by the original drilling and by the cuttings from the tools finding an inlet to the old hole. The elimination of the cuttings in this way keeps the hole much cleaner, with less bailing than in the original drilling.

It will also be found that the underreamer is used less than in the first drilling. The formation seems to break to a greater width from the impact of the bit alone, and hard strata that occasioned the use of the underreamer when the hole was first drilled, are often undetected in the second drilling.

#### ULTIMATE CONDITION OF HOLE.

It can not be maintained that drilling past a string of casing, and carrying a second string of pipe to the intended depth past the old casing, leaves a hole in as perfect condition as it would be in the event

that sidetracking had not been necessary, but the general results of such work are highly encouraging. There is little more reason to expect trouble from a string of casing landed successfully by drilling past an old string than there would be if the conditions were otherwise, although the new string may suffer from the causes that occasioned the original casing to fail.

#### "SIDETRACKING" A COMMON PRACTICE.

Sidetracking casing is such a common, in fact, daily occurrence in many localities that citations from the hundreds of examples where such work has been successfully performed is unnecessary. One of the many instances of such work will be enough—that performed on well No. 4, of the American Petroleum Co., section 30, Coalinga, Calif. This well—an old producer at the time of the writer's knowledge of it—had 10-inch pipe broken off within, and successfully sidetracked on four different occasions. On the last occasion the 10-inch pipe was pulled, but more than 250 feet of the string was left in the hole. The bottom joint of the pipe pulled out was replaced with a new joint, a 10-inch shoe being used. The lost pipe was sidetracked, the new string landed, and the well put to pumping within two weeks.

In the example cited on page 26, where the pipe collapsed at 1,600 feet, the original depth of the hole was 2,210 feet. The 610 feet of hole, thus lost by the collapsing of the pipe, was redrilled in less than one-third of the time consumed in drilling the original hole.

#### TOOLS USED IN SIDETRACKING CASING.

Tools used in sidetracking casing are many and varied when the work does not proceed with the ease anticipated. They are largely a matter of individual choice and construction, however, and usually are dispensed with in favor of the ordinary drilling tools. Bits are sometimes drawn far out to one side until they are bootlike in appearance, upon the theory that the extended point will reach a troublesome sliver of the old pipe that may be obstructing the passage of the new pipe. Reamer bits, flat on the surface and rounded to the "full" of the hole, are also used, but although the reamer bit is recommended, unless the job is of an unusual kind, the ordinary drilling tools suffice for all purposes.

#### IMPORTANCE OF "CLEAN START."

In drilling past it has been proved that if the work be not unduly hurried in the beginning, and the pipe receives a clean start past the top of the old pipe, the work will progress more favorably than if this start is forced.

A bit is put to work, as in ordinary drilling, upon the top of the old pipe. After enough progress has been made for the insertion of a joint of casing, the pipe should be "tried." If the slivered casing obstructs the passage of the pipe, the hole should be underreamed until the barrier is forced into the wall, or broken off. When this happens the first joint of pipe will start past the old pipe. From now on ordinary drilling problems only are met, with the exception of an occasional troublesome sliver of the old pipe interfering enough to cause momentary delay.

#### ODD FEATURES OF SIDETRACKING PIPE.

The new casing should be raised only when unavoidable, as the old pipe often falls back into the hole if the casing is raised, thus necessitating a repetition of the work.

Turning the casing will often cause it to pass a sliver obstructing at an unexpected moment. On the other hand, an unfortunate turn of the casing will sometimes cause it to encounter an obstruction at a place in the hole through which it had previously passed freely. This action of the casing is referred to merely to illustrate the peculiar behavior of casing at times and not because it is of great importance.

After the initial start, the old pipe may not again be encountered. In most cases, however, when freedom from contact with the old pipe is maintained throughout the greater part of the redrilling, the bottom joint of the old string will be encountered and some trouble will be met in passing.

The balance of opinion as regards the choice of shoe to be used for this operation favors a plain shoe. It is contended that the occasional advantage obtained by a tooth shoe in eliminating a sliver is more than offset by the tendency of such a shoe to create slivers and catch others that a plain shoe would pass.

#### PRESSURES ALLOWABLE ON COMMERCIAL WELL CASINGS.<sup>a</sup>

The next step in the design of a water string is to determine the pressures that may be safely carried on the various sizes of commercial well casings. The most authentic information at hand on this subject is that published by Stewart.<sup>b</sup> This paper formed the basis of a study by Chester Naramore and R. S. Hazeltine, at Coalinga, Calif., in 1911. Later, Hazeltine presented a paper <sup>c</sup> on the results of Stewart's work as applied to the needs of the oil industry. Either of these papers will repay a thorough study by anyone facing water problems in drilling wells.

<sup>a</sup> From "Methods of shutting off water in oil and gas wells," by F. B. Tough. Bull. 163, Bureau of Mines, 1913, pp. 16-20.

<sup>b</sup> Stewart, R. T., Collapsing pressures of Bessemer steel lap-welded tubes, 3 to 10 inches in diameter: Trans. Am. Soc. Mech. Eng., May, 1906, pp. 730-822.

<sup>c</sup> Hazeltine, R. S., Collapsing pressure of steel tubes: West. Engineering, vol. 1, July, 1912, pp. 295-297.

The following abstract from Stewart's paper is of especial interest:

This research was undertaken for the purpose of supplying an urgent demand for reliable information on the behavior of modern wrought tubes when subjected to fluid collapsing pressure. Every means known to engineering science that could aid in the accomplishment of this undertaking has been used, and every possible effort made to get at the truth and have the research yield trustworthy data. It was planned and executed under the immediate direction of the author, at the McKeesport works of the National Tube Co., and has occupied for its completion, during a period of four years, the time of one to six men.

*Results of present research.*—The principal conclusions to be drawn from the results of the present research may be briefly stated as follows:

1. The length of tube, between transverse joints tending to hold it to a circular form, has no practical influence upon the collapsing pressure of a commercial lap-welded steel tube so long as this length is not less than about six diameters of tube.

2. The formulas, as based upon the present research, for the collapsing pressures of modern lap-welded Bessemer steel tubes, are as follows:

$$P=1,000 \left( 1 - \sqrt{1 - 1,600 \frac{t^2}{d^2}} \right) \quad (A)$$

$$P=86,670 \frac{t}{d} - 1,386 \quad (B)$$

Where  $P$ =collapsing pressure, pounds per square inch.

$d$ =outside diameter of tube in inches.

$t$ =thickness of wall in inches.

Formula A is for values of  $P$  less than 581 pounds, or for values of  $t \div d$  is less than 0.023, while formula B is for values greater than these.

These formulas, while strictly correct for tubes that are 20 feet in length between transverse joints tending to hold them to a circular form, are, at the same time, substantially correct for all length greater than about six diameters. They have been tested for seven sizes, ranging from 3 to 10 inches outside diameter, in all obtainable commercial thicknesses of wall, and are known to be correct for this range.

By the foregoing formulas one may compute the probable collapsing pressure for any commercial size of casing.

Methods have been given for determining the probable pressure that will be carried on the water string of a particular well, and also the method for computing the collapsing pressure of the casings; it remains to discuss the proper safety factors to use. Quoting again from Stewart's report:

Not one of the several hundred tubes tested failed at a pressure lower than 42 per cent less than the probable collapsing pressure, while 0.5 per cent of the number of tubes failed at 37 per cent and 2 per cent at 25 per cent less than that pressure. In other words, with an actual factor of safety of 1.75, \* \* \* not one of the tubes tested would have failed.

It would appear that:

1. For the most favorable practical conditions, namely, when the tube is subjected only to stress due to fluid pressure and only the most trivial loss could result from its failure, a factor of safety of 3 would appear sufficient.

2. When only a moderate amount of loss could result from failure, use a factor of 4.

3. When considerable damage to property and loss of life might result from a failure of the tube, then use a factor of safety of at least 6.

4. When the conditions of service are such as to cause the tube to become less capable of resisting collapsing pressure, such as the thinning of wall due to corrosion,

the weakening of the material due to overheating, the creating of internal stress in the wall of the tube due to unequal heating, vibration, etc., the above factors of safety should be increased in proportion to the severity of these actions.

These recommendations by Stewart are absolutely sound engineering, and if a safety factor of 3 were used in oil-well work some costly redrilling jobs might be avoided. At the same time such a procedure would not only increase the cost of material, but would frequently necessitate decreasing the size of the next string of pipe to be inserted in the well, a serious disadvantage. The drilling proverb, "Keep the hole as big as you can, as long as you can," is not to be lightly ignored.

Suppose, for example, it were necessary to shut off water in a well at a depth of 3,000 feet and a safety factor of 3 was to be used, Table 1 following shows that 6 $\frac{1}{4}$ -inch, 28-pound casing should fail with a water column of 9,380 feet. One-third of this, or 3,126 feet, would then be the permissible depth at which the casing could be used with a safety factor of 3. Similarly, 8 $\frac{1}{4}$ -inch, or larger, sizes would not meet the requirements with so large a safety factor. If no mistake occurs and the hole can be finished with one more string of pipe, nothing larger than 6 $\frac{1}{4}$ -inch open hole, or 4 $\frac{1}{4}$ -inch casing, can be used. In many localities a 4 $\frac{1}{4}$ -inch hole is undesirably small and if any misfortune is met with, such as a failure to make a successful water shut-off with the 6 $\frac{1}{4}$ -inch string, either a costly redrilling job has to be done or the hole must be finished with a 3-inch liner into the oil sands, or else the well must be abandoned.

TABLE 1.—*Collapsing pressures and capacities per linear foot of lapwelded steel casing of sizes commonly used in California.*

| Size.           | Weight per foot. | Outside diameter. | Inside diameter. | Thick-ness.    | Collaps-ing pres-sure per square inch. | Equiv-alent water column. | Water column with safety factor of 2. | Capacity per linear foot.    | Capacity per linear foot. |
|-----------------|------------------|-------------------|------------------|----------------|----------------------------------------|---------------------------|---------------------------------------|------------------------------|---------------------------|
| <i>Inches.</i>  | <i>Pounds.</i>   | <i>Inches.</i>    | <i>Inches.</i>   | <i>Inches.</i> | <i>Pounds.</i>                         | <i>Feet.</i>              | <i>Feet.</i>                          | <i>U.S.gals.<sup>a</sup></i> | <i>Cu.feet.</i>           |
| 4 $\frac{1}{8}$ | 16               | 4.750             | 4.082            | 0.334          | 4,710                                  | 10,850                    | 5,425                                 | 0.6792                       | 0.0908                    |
| 4 $\frac{1}{2}$ | 12.85            | 5.000             | 4.506            | .247           | 2,900                                  | 6,680                     | 3,340                                 | .8281                        | .1107                     |
| 4 $\frac{3}{4}$ | 15               | 5.000             | 4.424            | .288           | 3,610                                  | 8,320                     | 4,160                                 | .7982                        | .1067                     |
| 5 $\frac{1}{8}$ | 20               | 6.000             | 5.352            | .324           | 3,290                                  | 7,580                     | 3,790                                 | 1.1677                       | .1561                     |
| 6 $\frac{1}{8}$ | 20               | 6.625             | 6.049            | .288           | 2,380                                  | 5,480                     | 2,740                                 | 1.4916                       | .1994                     |
| 6 $\frac{1}{2}$ | 24               | 6.625             | 5.921            | .352           | 3,220                                  | 7,420                     | 3,710                                 | 1.4295                       | .1911                     |
| 6 $\frac{3}{4}$ | 26               | 6.625             | 5.855            | .385           | 3,650                                  | 8,410                     | 4,205                                 | 1.3974                       | .1868                     |
| 6 $\frac{7}{8}$ | 28               | 6.625             | 5.791            | .417           | 4,070                                  | 9,380                     | 4,690                                 | 1.3667                       | .1827                     |
| 6 $\frac{3}{4}$ | 20               | 7.000             | 6.456            | .272           | 1,980                                  | 4,560                     | 2,280                                 | 1.6988                       | .2271                     |
| 6 $\frac{7}{8}$ | 26               | 7.000             | 6.276            | .362           | 3,100                                  | 7,140                     | 3,570                                 | 1.6061                       | .2147                     |
| 6 $\frac{7}{8}$ | 28               | 7.000             | 6.214            | .393           | 3,480                                  | 8,020                     | 4,010                                 | 1.5739                       | .2104                     |
| 6 $\frac{7}{8}$ | 30               | 7.000             | 6.154            | .423           | 3,850                                  | 8,870                     | 4,435                                 | 1.5440                       | .2064                     |
| 7 $\frac{1}{8}$ | 26               | 8.000             | 7.386            | .307           | 1,940                                  | 4,470                     | 2,235                                 | 2.2240                       | .2973                     |
| 8 $\frac{1}{4}$ | 28               | 8.625             | 8.017            | .304           | 1,670                                  | 3,850                     | 1,925                                 | 2.6204                       | .3503                     |
| 8 $\frac{1}{2}$ | 32               | 8.625             | 7.921            | .352           | 2,150                                  | 4,950                     | 2,475                                 | 2.5583                       | .3420                     |
| 8 $\frac{3}{4}$ | 36               | 8.625             | 7.825            | .400           | 2,630                                  | 6,060                     | 3,030                                 | 2.4962                       | .3337                     |
| 8 $\frac{3}{4}$ | 38               | 8.625             | 7.775            | .425           | 2,880                                  | 6,640                     | 3,320                                 | 2.4648                       | .3295                     |
| 8 $\frac{7}{8}$ | 43               | 8.625             | 7.651            | .487           | 3,510                                  | 8,090                     | 4,045                                 | 2.3863                       | .3190                     |
| 9 $\frac{1}{8}$ | 33               | 10.000            | 9.384            | .308           | 1,280                                  | 2,950                     | 1,475                                 | 3.5899                       | .4799                     |
| 10              | 40               | 10.750            | 10.054           | .348           | 1,420                                  | 3,270                     | 1,635                                 | 4.1210                       | .5509                     |

<sup>a</sup> Figures in this column determined by multiplying corresponding values in cubic feet by 7.4805.

TABLE 1.—*Collapsing pressures and capacities per linear foot of lapwelded steel casing of sizes commonly used in California—Continued.*

| Size           | Weight<br>per<br>foot. | Outside<br>diameter. | Inside<br>diameter. | Thick-<br>ness. | Collaps-<br>ing pres-<br>sure per<br>square<br>inch. | Equi-<br>valent<br>water<br>column. | Water<br>column<br>with<br>safety<br>factor<br>of 2. | Capacity<br>per<br>linear<br>foot. | Capacity<br>per<br>linear<br>foot. |
|----------------|------------------------|----------------------|---------------------|-----------------|------------------------------------------------------|-------------------------------------|------------------------------------------------------|------------------------------------|------------------------------------|
| <i>Inches.</i> | <i>Pounds.</i>         | <i>Inches.</i>       | <i>Inches.</i>      | <i>Inches.</i>  | <i>Pounds.</i>                                       | <i>Feet.</i>                        | <i>Feet.</i>                                         | <i>U. S. gals.</i>                 | <i>Cu. feet.</i>                   |
| 10             | 45                     | 10.750               | 9.960               | 0.395           | 1,800                                                | 4,150                               | 2,075                                                | 4.0440                             | 0.5406                             |
| 10             | 48                     | 10.750               | 9.902               | .424            | 2,030                                                | 4,680                               | 2,340                                                | 3.9976                             | .5344                              |
| 10             | 54                     | 10.750               | 9.784               | .483            | 2,510                                                | 5,780                               | 2,890                                                | 3.9026                             | .5217                              |
| 11             | 47                     | 11.750               | 11.000              | .375            | 1,380                                                | 3,180                               | 1,590                                                | 4.9334                             | .6595                              |
| 11             | 60                     | 11.750               | 10.772              | .489            | 2,220                                                | 5,120                               | 2,560                                                | 4.7307                             | .6324                              |
| 11½            | 40                     | 12.000               | 11.384              | .308            | 840                                                  | 1,940                               | 970                                                  | 5.2827                             | .7062                              |
| 12½            | 40                     | 13.000               | 12.438              | .281            | 500                                                  | 1,150                               | 575                                                  | 6.3083                             | .8433                              |
| 12½            | 45                     | 13.000               | 12.360              | .320            | 750                                                  | 1,730                               | 865                                                  | 6.2298                             | .8328                              |
| 12½            | 50                     | 13.000               | 12.282              | .359            | 1,010                                                | 2,330                               | 1,165                                                | 6.1497                             | .8221                              |
| 12½            | 54                     | 13.000               | 12.220              | .390            | 1,210                                                | 2,790                               | 1,395                                                | 6.0869                             | .8137                              |
| 13½            | 50                     | 14.000               | 13.344              | .328            | 640                                                  | 1,470                               | 735                                                  | 7.2598                             | .9705                              |
| 15½            | 70                     | 16.000               | 15.198              | .401            | 790                                                  | 1,820                               | 910                                                  | 9.4150                             | 1.2586                             |

### FISHING WITH OVERSHOT.

Of the innumerable tools for pipe fishing, the writer has chosen the overshot (fig. 8) as being sufficiently important for detailed description.

Overshots (see Pl. I, *C*, p. 16) have three flat springs about 16 inches long,  $1\frac{1}{4}$  inches wide, and  $\frac{1}{4}$  inch thick, but varying in size to correspond to the size of the overshot. The springs are held erect within a steel bowl. The overshot is run upon pipe larger than the string lost in the hole. When the overshot comes in contact with the top of the lost pipe, it slips over that pipe, and travels down over the collars. If unhindered by cavings or other obstacles, the overshot can be run to the bottom of the hole. The well then has one string of pipe within another. When the overshot is raised the upright springs catch under a collar of the lost or inner pipe and this pipe, if free, can then be pulled; however, should it not be free, and the outside string be known to be the stronger, the inner pipe may be pulled apart. The overshot, although a delicate appearing tool, is capable of withstanding considerable strain. This tool is an excellent one for catching tubing or casing that has been dropped and is broken and crooked, provided it is reasonably certain that the casing or tubing has not become fast in the hole so that excessive strains will be required to pull it.

### FISHING WITH CASING SPEARS.

There are many types of casing spears manufactured for fishing out casing. However, they may be classified under two heads—bulldog and trip spears.

Every care should be taken to avoid running a spear below a breach in the pipe that will permit débris or broken pieces of casing to fall upon the spear. Under such adverse circumstances the best trip spears are likely to "bulldog" in the pipe and they are a very stubborn tool to remove when once "fouled."

Regardless of selling advertisements to the contrary, spears of whatever make will damage pipe, at the point of contact of slips and pipe, if heavy jarring is continued too long in one place without changing the "hold." When the hold should be changed is a matter depending entirely upon the judgment of the driller and the weight and condition of the pipe for which he is fishing.

#### BULL-DOG SPEARS.

Bulldog spears (fig. 9, p. 34) are so constructed that once the spear is run into the pipe being fished for, it can not again be raised without taking all or part of the pipe with it. In other words, the hold may be broken and a lower hold taken, but the spear can not be pulled up without gripping the pipe. Before running this tool, if a stubborn jarring job is anticipated, due care should be taken that all equipment is in good condition, because "something has to come." The pipe must either be freed in toto or jarred apart and an upper part removed.

#### TRIP SPEARS.

Trip spears (fig. 10, p. 35) are so constructed that the hold may be broken and the spear withdrawn at the will of the driller. Trip spears are made with two and four slips. The 4-slip spear is intended to be less injurious to the pipe than the 2-slip spear. The spear that is less liable to damage pipe permits the longest "jarring" in one spot without changing "holds."

For stubborn jobs, whenever obtainable, trip spears should be used in preference to bull-dog spears. Should any accident occur and be detected, such as the slow unstranding of a wire cable due to a broken strand, or should the job prove stubborn enough to require a change of method, or should any one of innumerable reasons demand that the hold be broken and the tool pulled out, the use of the trip spear would permit this being done.

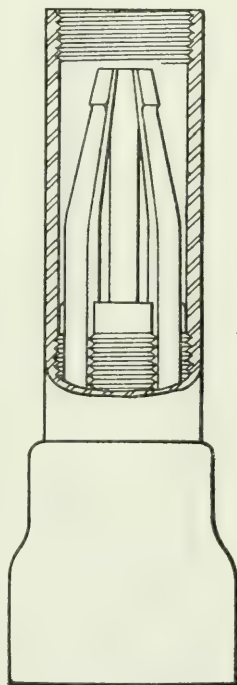


FIGURE 8.—Overshot. The springs pass down over pipe and couplings, but catch under a coupling when pulled up.

## JARRING UP WITH SPEAR.

Assume a hole to be 2,300 feet deep and the pipe frozen. Light driving at the surface with clamps and drivehead would probably be the first step after precaution was taken to keep the pipe from dropping. This failing, the jar-down spear would be used (see fig. 3). Should the jar-down spear also fail, the "friction" would be ascertained by obtaining vibration before withdrawing the spear. A trip drive-up spear would now be placed upon the fishing jars left on the bottom of the stem when the jar-down spear was removed. Assume that the "friction" has been found to be behind the last 200 feet of pipe or between depths of 2,100 and 2,300 feet. The "stretch" of the casing would first be taken and held; a hold would then be taken in the pipe with the spear at 2,270 feet or about midway in the second joint from the bottom, or midway in the shoe joint, if preferred.

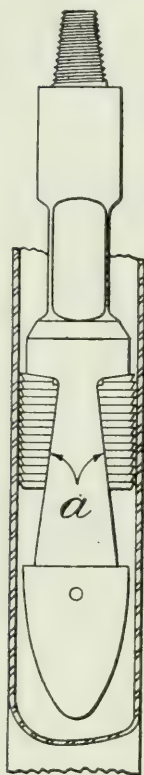
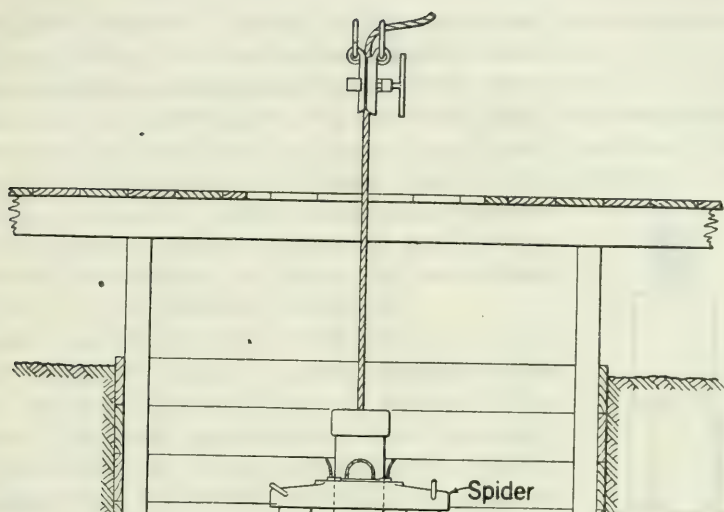


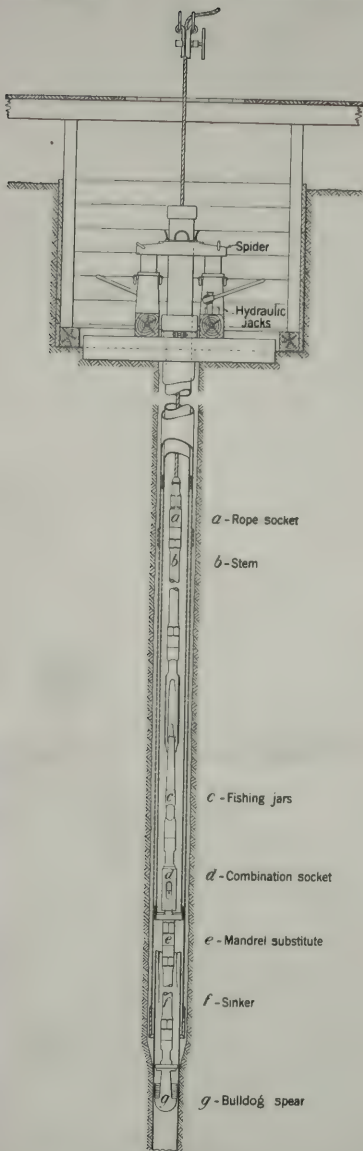
FIGURE 9.—Bulldog casing spear. Once the tool takes hold it can not be withdrawn, because upward movement will cause the slips *a* to slip down the inclined plane and lodge against the pipe.

Jarring up would now be started. The hold would be changed, from time to time, according to the possibility of its injuring the pipe. Signs of vibration in the pipe would be watched. The spear having hold within the part of the casing bound by wall "friction," no vibration would be had unless movement, though ever so slight, were obtained. Should vibration be obtained, it would start faintly with the first slight movement of the casing. This vibration would increase as the pipe became more free. When the vibration was distinct enough to justify the effort, the trip spear would be withdrawn (it will be noted that a bull-dog spear could not be withdrawn) and the pipe would be worked with the engine. Movement having been obtained, the success of the operation should be assured, although a repetition of the process might be necessary before the pipe would pull.

## FISHING WITH SPEAR AND HYDRAULIC JACKS.

If vibration were not obtained and the pipe not freed as described above a pair of hydraulic jacks might be used to assist in loosening the pipe. Each of these jacks is usually capable of lifting 100 tons. They should be placed upon a firm footing (see Pl. II), one on each side of the casing, and the ordinary small spider placed over the pipe with an end resting upon each jack. The pipe is then "stretched" to the utmost margin of safety, and the slips inserted in the spider





STRING OF FISHING TOOLS.

to hold this "stretch." A hold in the pipe is then taken with a trip spear, and jarring up is resumed as formerly described.

The jacks are screwed against the spider in unison with the jarring whenever it is believed that the pipe will stand increased strain. Indications that the pipe has started an upward movement are expected. Certainty that movement has started is known only if vibration is obtained. Unless vibration is obtained, continued jacking will part the casing, but if vibration should be obtained, the jacks may be operated more freely as the vibration increases.

Should the pipe part at a coupling above the spear, because of excessive power applied to the jacks, the pipe could be allowed to remain in the hole until the spear is pulled out. The pipe could then be withdrawn. If a bull-dog spear were used, the spear could not easily be withdrawn, and it might be necessary to "strip" all the pipe out over the cable, a long and laborious process compelling the passing of the drilling cable through each stand of pipe as the pipe is withdrawn. Also, cavings would settle upon the bull-dog spear when the loose pipe was withdrawn if the wall of the hole was not held by an outside string of casing, at the point where the pipe parted, whereas with a trip spear the mere setting of the pipe together until the hold of the trip spear was broken would be sufficient to exclude the cavings until the spear was pulled out.

#### BREAKING THE HOLD OF A "BULL-DOGGED" SPEAR.

When casing spears of any make get "bull-dogged" or "fouled" in the pipe, making their removal difficult, the slips can often be worn smooth by "hitching on" so that the jars will hit both ways. If the jars hit both upon the up and down strokes this will start the slips upon the spear to working. Sometimes the slips cut a channel through the heavy steel at the bottom of the spear and drop into the hole, but more often the teeth of the slips are "rasped off" by working the slips up and down against the pipe until they are so smooth that they refuse to catch the pipe. The spear can then be pulled with some difficulty.

A "bull-dogged" spear can also be removed from the hole by running it below the shoe, and taking a hitch that will cause the slips to strike the shoe on the up stroke. This procedure will cause the slips



FIGURE 10.—Trip casing spear. When the spear is driven upon with tools, the small trigger *a* snaps into place, as shown, permitting the spear to trip and be withdrawn.

to shear a passage at the bottom of the spear or break out the dovetails, thus permitting the slips to drop into the hole below. This method is very severe on the shoe, but is effective and can be used as a last resort. Care should be taken to prevent a spear from bulldogging unintentionally, as complications that may cause a serious fishing job are possible in breaking the hold by the methods just described.

#### FISHING WITH MANDREL SUBSTITUTE, SPEAR, AND JACKS.

In construction, a mandrel substitute (see Pl. II, p. 34) is like a wire-cable socket except that no cable hole is bored in it, and it has between the wrench squares and the "neck" a thread fitted to a pipe coupling. It is used where a short string of pipe has been left frozen in the bottom of a hole. The top joint of this pipe may be split (see Pl. II). The method of use is as follows:

The mandrel substitute is screwed tightly into a pipe coupling of the same size as the lost "string." The neck of the substitute is inside the pipe, and the bottom of the pipe is "plugged" by the substitute. A short stem, or "sinker," long enough to reach below the split (if present) in the top joint of the lost string, is placed upon the mandrel substitute. Either a bulldog or trip spear may be used upon the stem. The use of jars between stem and spear is seldom necessary, and when used the jars frequently cause trouble. Because of the small space in which jars have to operate in this work, and the tendency of a spear to take a lower hold when "knocked" further down a hole, jars are only occasionally an aid in breaking a hold. Usually a bulldog spear is used without the aid of jars, upon the theory that "something has to come."

Assuming that jars<sup>a</sup> are not used, the tools should now be "strung" as follows: The mandrel substitute is screwed into the coupling, a short stem is screwed into the mandrel substitute, and a spear screwed into the stem.

The pipe with the tools attached, as described, is run into the hole until the spear enters the lost pipe and is below the split, if such exists, in the top joint (see Pl. II). The fishing string is then raised and the "stretch" held with a spider placed upon hydraulic jacks, as described on page 34. The cable tools are now used. Fishing jars are placed upon the bottom of the stem, and a combination socket (see Pl. II) with "slips" fitted to the neck of the mandrel substitute is screwed upon the jars. The tools are now run into the pipe and the combination socket takes a hold upon the neck of the mandrel substitute. A hitch is taken with the cable tools and jarring up is commenced. The process is now identical in operation to that described

<sup>a</sup> Driving the pipe at the surface to break the hold should trip a trip spear as readily as would the jar.

on page 35. The jacks are operated in unison with the jarring, and the operation is continued until the frozen pipe is freed or parted. As the hold of the combination socket is easily broken when desired, the tools may be withdrawn at will and the pipe pulled with the portion of the lost string jarred loose. The operation can then be repeated. For successful fishing with a mandrel substitute, the walls of the hole must either stand up or be held in place by a protecting string or casing.

### CUTTING CASING IN THE HOLE.

When only the lower part of a string of pipe is of service in a hole, the recovery of the unserviceable part of the pipe is often desirable. For example, a hole has 450 feet of  $12\frac{1}{2}$ -inch pipe within it, 1,500 feet of 10-inch pipe has been landed and the water shut off with this string. At 2,000 feet the 8-inch pipe freezes and is permitted to remain in place. The well is finished by inserting 2,500 feet of  $6\frac{5}{8}$ -inch casing. If the chance of any of the outside strings collapsing or "going bad" is considered slight, the pipe could be cut off near the bottom of each protecting well string and the upper part of the pipe recovered without damage to the hole. The  $6\frac{5}{8}$ -inch pipe could be cut off at 1,950 feet and this part recovered, leaving the lower 550 feet in the hole. Such a cut would leave a 50-foot lap of  $6\frac{5}{8}$ -inch pipe extending up into the  $8\frac{1}{4}$ -inch. Similarly, 1,450 feet of  $8\frac{1}{4}$ -inch casing could be recovered, leaving the lower 550 feet in place and a 50-foot lap of  $8\frac{1}{4}$ -inch pipe extending up into the 10-inch. After cutting the pipe, either the top of each cut joint in the hole would have to be swaged until it "belled out" tight against the outer string, or else an "adapter" (fig. 11), would have to be placed on the top of the cut joint. The adapter fits over the cut joint and is prevented from sliding down over the pipe by means of a "shoulder" which rests on the top of the pipe. The top of the adapter is tapered and the outside is flush with the casing through which it is inserted. Were the pipe not "belled out," or an adapter used, the tools would catch on the cut pipe in passing down the hole. When more than one string of pipe is to be cut, each adapter should be set before the next larger string is removed from the hole.

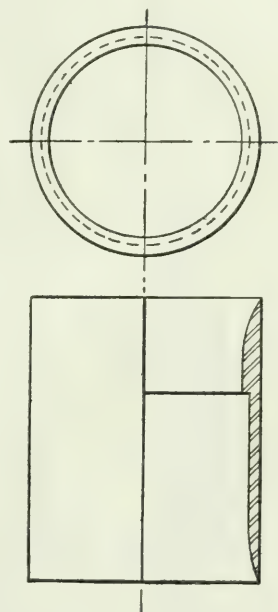


FIGURE 11.—Casing adapter, for adapting one size of casing to another, and permitting tools to be lowered into the well.

## USE OF CUTTERS.

The similarity of the various casing cutters now extensively used, makes their operation identical. Knives, *a* (see fig. 12), as in ordinary pipe cutters, varying only in size, are held in sliding steel blocks, *b*, mounted in a cylindrical steel frame, *c*. The knives are forced against the pipe by a tapered steel mandrel, *d*, inserted behind the steel blocks, *b*, through a hole in the center of the steel frame.

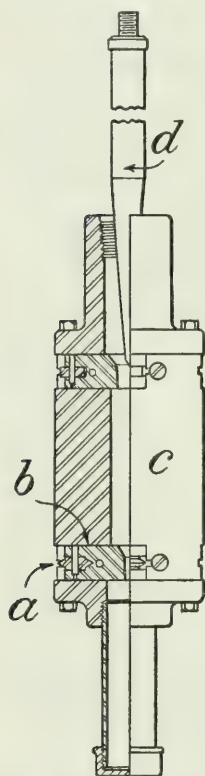


FIGURE 12.—Casing cutter.

*a*, Knives; *b*, steel blocks;  
*c*, steel frame; *d*, mandrel.

Before "running" the cutter, enough "stretch" should be taken upon the casing and maintained by means of elevators or spider and slips to cause the pipe, when cut in two, to jump just enough to give notice that the operation has succeeded. This stretching also eliminates the problem of "slack" pipe that would otherwise arise. After the pipe is stretched, the cutter is placed on tubing and run into the hole to the desired depth. A ball-bearing race, though not absolutely essential, should be placed between the elevators and the tubing coupling, immediately above them. This race makes the turning of the tubing less difficult and acts to prevent the tubing from screwing up in the couplings and raising the cutter when the tool is turned.

A set of long-stroke jars small enough to enter the tubing and with a pin of the same size and thread as a sucker-rod pin are placed above the mandrel. From two to four iron sucker rods are placed above the jars. The connected equipment is attached to the sand line, run into the tubing, and permitted to strike lightly upon the cutter, where it will stop. The tubing is then turned by hand power. The weight of the rods

above the mandrel forces the blocks containing the knives out against the casing. Sometimes this weight is sufficient for the work, but when it is not, and the cutter turns with so little effort as to convince the drillers that it is making little progress, the jars between the mandrel and sucker rods may be operated by hand, or engine, or by raising and dropping the sand line. When the rods are raised with the sand line and the jars parted without pulling the mandrel out of the cutter, the mandrel drives farther between the sliding blocks each time the rods fall against it and forces the knives farther into the pipe metal and holds

them there. The mandrel should not be driven between the blocks too tightly or the tubing can not be turned.

Usually 20 to 40 minutes' turning of the tubing is required to cut the casing. If the casing is not cut after  $1\frac{1}{2}$  hours' turning and the tubing is pulled, it will probably be found that the knives were forced too rapidly by the mandrel and were broken. They can then be replaced and the operation repeated. When the casing is cut it will jump from the stress obtained and must be held before running the cutter. The mandrel and rods should then be pulled, the tubing should be raised gently until the cutters are started into the upper pipe and should then be pulled; afterwards the loose casing should be pulled. An adapter (see fig. 11) should then be inserted over the cut joint in the hole or else the top of the joint should be "belled out" with a swage, as formerly described.

### SPLITTING CASING IN THE HOLE.

Casing splitters<sup>a</sup> are operated by driving down with the drilling tools, with long-stroke jars on the bottom of the stem and the splitter (see fig. 13) attached to the jars.

The simple construction of the splitter makes it a safe and practical tool. The impact of the jars when the tools strike causes a knife, *a*, in a sliding block, *b*, which is forced up and against the pipe from the bottom by a mandrel, *c*, held in place by tension of the spring, *d*, against the pipe, to cut through the pipe. The knife is held stationary in the block, *b*, by a steel pin, *e*, extending through the block and the knife. The steel pin also holds the block in the frame of the splitter. Before running the splitter into the casing, the spring, *d*, is raised up the mandrel by compressing with the fingers the small trigger, *g*, at the bottom of the mandrel. When the tool is lowered in the hole, there is enough pipe friction upon the spring to prevent its dropping back over the trip trigger. Should the spring lack tension and in some manner drop back while the splitter is being run into the hole, the mandrel would at once raise against the block and a hole would be forced in the pipe by the jars striking.

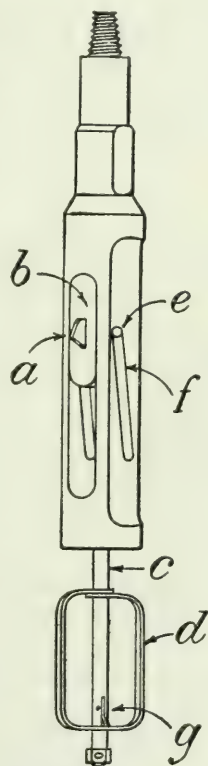


FIGURE 13.—Casing splitter. *a*, Knife; *b*, sliding block; *c*, mandrel; *d*, spring; *e*, steel pin; *f*, inclined slot; *g*, trigger.

<sup>a</sup> Wagy, E. W., Uses of perforated casing and screen pipe in oil wells: Tech. Paper 247, Bureau of Mines, 1919, p. 9.

When the tool is lowered to the desired depth it is then raised, the mandrel draws up through the spring, and the trigger snaps into place. Then the splitter is tripped. The knife will thrust a hole through the pipe with the first impact of the jars. Care must then be taken to keep the jars from "hitting up." Should the jars "hit up," the knife will be withdrawn from the pipe and will probably be broken. After "hitching on" the splitter will drive readily, cutting a slot in the pipe in its progress, until a coupling is reached. The progress of the knife will be retarded by the coupling but not stopped. When the coupling is split, the pipe can then be pulled, although the coupling sometimes fails to spread enough to permit pulling without light driving of the pipe at the top by clamps and drive head.

#### USES OF CASING SPLITTERS.

Casing splitters are most commonly used to recover casing when a hole is about to be abandoned, and when the work involved in freeing the pipe, so that the entire string can be recovered, would prove too expensive.

Casing splitters may also be used as perforators<sup>a</sup> to cut holes in casing. Some splitters are constructed with two knives, by the use of which two separate cuts are obtained. Splitters will not always take the place of cutters, as the former are liable to leave the uppermost joint of pipe left in the hole in a split condition, which is undesirable for a hole in which further work is to be done.

A slight stress may be held upon pipe about to be split, but the stress should not be excessive, as the jarring down upon the coupling being cut increases the stress on the upper couplings, and excessive stress can cause the pipe to part above the splitter.

When pipe has collapsed or is so "bad" as to make the redrilling of a hole necessary, if the pipe will not pull, it may be split above the "bad place" more easily than it can be cut and with equally satisfactory results.

In splitting pipe, the wrist pin should be placed in either the first or second hole of the crank shaft in order to avoid breaking the knife with too forcible a blow. This will also minimize the chances of the jars striking both ways.

#### SHOOTING OFF CASING.

A study of various Bureau of Mines publications, particularly Technical Paper 6,<sup>b</sup> has convinced the writer that a lack of techni-

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<sup>a</sup> Wagy, E. W., Uses of perforated casing and screen pipe in oil wells: Tech. Paper 247, Bureau of Mines, 1919, pp. 10-17.

<sup>b</sup> Snelling, W. O., and Cope, W. C., The rate of burning fuse as influenced by temperature and pressure: Tech. Paper 6, Bureau of Mines, 1912, 28 pp.

cal knowledge of fuse and explosives is responsible for some of the unexplained fatalities that have occurred in the oil fields.

Investigations throughout the various fields have proved that the recent tendency is to resort to the old-fashioned methods of shooting off casing, and to exact from the drilling crew a service that should be placed only in professional hands. Professional shooters (this does not refer to nitroglycerin shots used to stimulate oil production) place their shots in galvanized-iron containers and explode the charge electrically, the wire usually being lowered in the hole with the shell, by means of the sand line. Because of its being apparently simple and practical, the advantages and disadvantages of this method of shooting casing should be thoroughly investigated before the method is discarded.

Many operators contend that the shots placed in galvanized-iron containers and exploded electrically by professional shooters are responsible for the occasional joint of split pipe found as much as a thousand feet above the shot. The writer is aware that pipe is so damaged by occasional shots, but is not convinced that the old tubing method of shooting is an absolute preventive of such damage.

#### WHY CASING IS SHOT.

To recover frozen casing from wells about to be abandoned, it frequently pays to shoot the casing off near the bottom and pull the remainder. In case the pipe will not pull, a shot may be placed higher, and this procedure continued until the pipe will pull. Shooting off pipe in this manner does away with a large expenditure for labor and equipment necessary in driving, cutting, splitting, etc. Although a greater amount of pipe is lost than would be in driving, cutting, and splitting, this loss is offset by the saving of labor, haulage, equipment, etc.

If a well is cemented and the water has not been shut off, many operators run a drive-down spear into the well, ascertain the "friction" on the pipe by raising the spear until vibration is obtained, and shoot the pipe into shreds the entire length of the friction. The point of friction being above the top of the cement, the pipe is freed. The pipe is then pulled, all damaged joints removed, a shoe placed upon the bottom joint, and the hole redrilled and recemented.

#### SHOOTING WITH TUBING.

One method of placing a shot for the purpose of shooting off casing for its recovery is as follows:

A steel nipple  $4\frac{1}{2}$  inches in diameter and 3 feet long has a plug securely screwed into the bottom coupling. In the top coupling is a bushing  $4\frac{1}{2}$  inches in external diameter and 2 inches in internal diameter. Two joints of 2-inch tubing are screwed into the top of

the bushing (see fig. 14). The charge of stick gelatin or dynamite—20 to 40 sticks of 60 per cent explosive—is placed in the container of 4½-inch pipe at the bottom. The tubing has a plug in the top, making the container water-tight. An explosive cap crimped to the fuse is inserted in a stick of the explosive. The paper at the top of the stick of explosive is wrapped with string to the fuse. This squib is lowered through the tubing by means of the fuse until it rests upon the explosive in the container at the bottom of the tubing. The fuse is then cut off at the top of the tubing and lighted. The plug is screwed back into the tubing. The container is now lowered by the sand line until it is at the required spot in the casing. After the shot it will be found that the sand line is uninjured by the explosion.

When it is desired to place an extended shot of several hundred feet, as in cemented but leaking pipe, the vibration is obtained by a drive-down spear, as previously explained. On the assumption that a hole has 2,000 feet of pipe cemented within it and the vibration is found at 1,700 feet, a 300-foot shot would be necessary to free the pipe. An entire string of 2½-inch tubing could be used with a plug in the bottom joint and the lower 300 feet of the tubing could be filled with stick gelatin. The caps could rest in a small receptacle at the top of the explosive (see fig. 15). An iron dropped through the tubing would explode the charge and shatter the casing and tubing for 300 feet.

As both methods of tubing shooting described here are done under water, unexpected damage is seldom caused. With the latter method, the tubing can be pulled and will be undamaged above the place where the shot was placed. The danger in this method of shooting is evident when it is realized that any heavy piece of débris falling through the tubing would explode the shot.

### ILLUSTRATIVE FISHING JOBS.

The writer has chosen a few actual fishing jobs in order to illustrate the application of fishing tools by skilled men in daily practice.

#### MYERS NO. 3 WELL, UNION OIL CO., CALIFORNIA.

At Myers No. 3 well, of the Union Oil Co., in a California field, the drillers were E. P. Weiman, Boyd Smith, J. A. McMillan, and Superintendent J. A. Kammerdiner. In this hole two strings of pipe were cemented together. It was desired to loosen and recover the inner pipe without disturbing the outer pipe, which was a water string. The hole had within it 3,140 feet of 10-inch pipe. Within the 10-inch pipe was 3,300 feet of 8¼-inch pipe. When the well was cemented, the cement had raised between the two strings of pipe to a height of 1,930 feet from the surface. This left 1,210

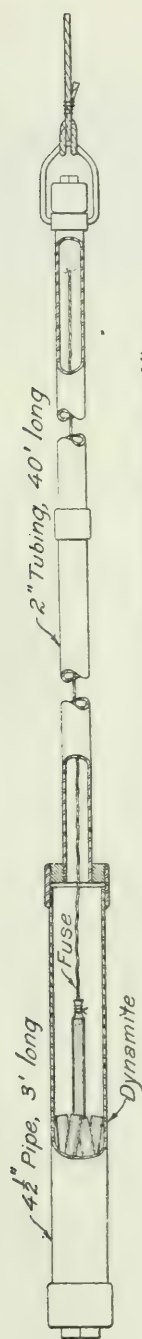


FIGURE 14.—Tubing shell for sand-line shot, used to shoot off casing. Run on sand line.

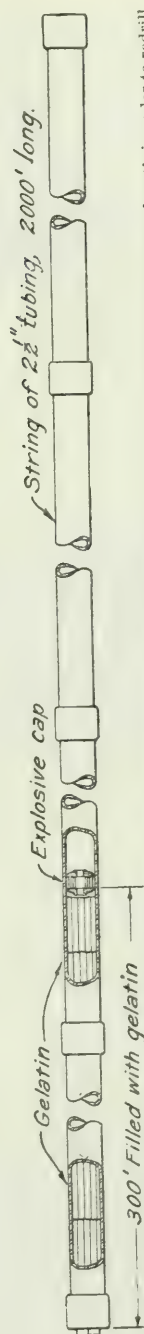
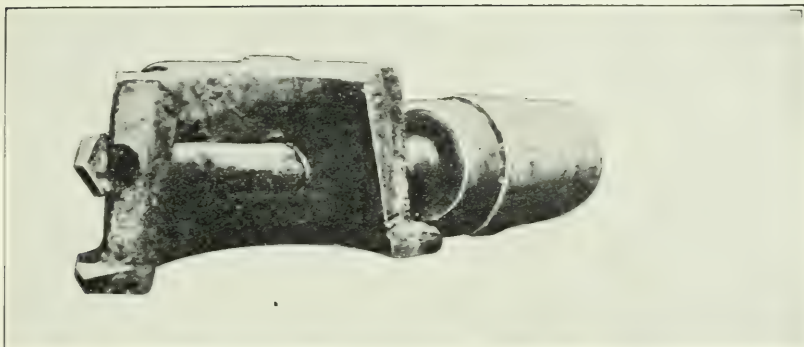


FIGURE 15.—Complete string of tubing with the lower joints filled with explosive. Used for extended shot to shatter casing for a given length in order to redrill.

feet of 10-inch and 8 $\frac{1}{4}$ -inch pipe firmly cemented together at the bottom of the hole. The 8 $\frac{1}{4}$ -inch pipe was cut off with casing cutters at 1,930 feet, and this amount of pipe was recovered. Then the 8 $\frac{1}{4}$ -inch pipe remaining in the hole was recovered in short sections by splitting the collars. Sometimes only the collar at the lower end of the top joint would be split. A trip spear would then be run and this joint would be jarred out of the encircling cement and pulled. Two or three joints at a time were the most the drillers ever tried to recover after having made a successful but laborious effort to obtain five joints at one time. This procedure was continued until the 1,210 feet of 8 $\frac{1}{4}$ -inch pipe cemented within the 10-inch pipe was recovered; 160 feet of 8 $\frac{1}{4}$ -inch pipe still remained in the hole below the 10-inch pipe. This pipe was sidetracked with a new string of 8 $\frac{1}{4}$ -inch casing, which was successfully landed at 3,600 feet. Also, 4,278 feet of 6 $\frac{1}{4}$ -inch casing was landed, and the time the writer obtained this information, 4 $\frac{1}{2}$ -inch pipe was still being carried at a depth of 4,595 feet. The cleaning of this hole took six weeks, and the 10-inch water string was not injured.

#### LAMERCED NO. 13 WELL, UNION OIL CO., CALIFORNIA.

At the Lamerced No. 13 well, of the Union Oil Co., in California, the drillers were Omar Hinds, Robert Graham, and Harvey Hoxworth. The hole was 2,411 feet deep. In reaming with a rotary a 4-way bit was lost at 2,000 feet. This bit was then 411 feet off bottom. Seventy feet of drill pipe had been left upon the top of the bit, but as the top joint had been ground up, by rotating with the pipe before it was discovered that the bit was lost, only 50 feet of pipe remained upon the top of the bit. Grabs were run, and the remaining half of the top joint of pipe, twisted into a knot about 18 inches long, was recovered. The remaining 50 feet of pipe was fished out with an overshot (see fig. 15, p. 43), but the bit had come out of the drill collar and remained in the hole. A 10-inch combination socket was now run with 5-inch by 6-inch pin slips to catch the bit, and a small piece of pipe was recovered. A mill (Pl. I, *D*, p. 16) was run until the drillers were certain it had reached the bit; then the mill was pulled and replaced by a set of jars over a 12 $\frac{1}{2}$ -inch combination socket. The combination socket gripped the bit, but the bit would not pull. The drill pipe was now swung against the bit by using a jerk line, but the bit still held firm. The hold of the combination socket was then broken by rotating, with water circulating around the jars until the slips mudded up. The combination socket was replaced with a spud (see Pl. I, *D*). The pipe was worked up and down and circulation maintained through the spud. The spud was then pulled and the bit was fished out with the 12 $\frac{1}{2}$ -inch combination socket fitted with 7 $\frac{3}{4}$ -inch slips.



A. DRILLED BUSHING, WITH DRILL IN PLACE.



B. DRILLED BUSHING.



C. DRILLED BUSHING, ANOTHER VIEW.



D. DRILLED BUSHING, DRILL REMOVED.



**AN UNUSUAL FISHING JOB.**

A rotary table bushing was dropped in a rotary hole on the Amalgamated lease in California. A hole about 4 inches in diameter was drilled through the bushing by rotating upon it a steel drill. After the drill had cut a hole, the thread near the top of the drill entered the hole. The thread, being tapered slightly, tightened enough as it screwed up to warn the driller when to stop rotating the pipe. The pipe was then pulled and the bushing recovered. Drilling the hole took but 40 minutes turning of the pipe. A view of this bushing, with the drill still in it, is shown in Plate III, *A*. Views of the bushing with the drill removed are shown in Plate III, *B*, *C*, and *D*. The double hole in the side of the bushing, shown in Plate III, *C*, was made by the drill cutting out a part of the bushing where it was cored, causing a second and unnecessary hole in one side of the bushing.

**LUBRICANTS FOR ROTARY TOOL JOINTS AND FOR CASING THREADS.**

The following formulas for lubricants were supplied by E. S. Durward, of the Shell Oil Co., Coalinga, Calif.

*Formula for lubricant for rotary tool joints.*

|                                        | Per cent. |
|----------------------------------------|-----------|
| Tallow.....                            | 33.4      |
| Starling white lead ground in oil..... | 23.2      |
| Graphite.....                          | 2.9       |
| Cylinder oil.....                      | 40.5      |

Melt tallow, add white lead, mixing well. Then add oil, stirring continually. Then add graphite and mix all together.

*Formula for lubricant for casing threads.*

|                                        |           |     |
|----------------------------------------|-----------|-----|
| Tallow.....                            | pounds..  | 200 |
| Sterling white lead ground in oil..... | do....    | 300 |
| Graphite.....                          | do....    | 24  |
| Lard oil.....                          | gallons.. | 30  |

Mix lead with some oil, also graphite with some oil, then melt the tallow. Finally mix everything together and keep stirring until thoroughly mixed.

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